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A GENERAL DIFFERENTIAL EQUATION IN THE THEORY OF THE DEFORMATION OF SURFACES.

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The labors of many geometers, notable among whom are Lagrange and Gauss, have brought to a high state of perfection and generality the theory of the orthomorphic representation of one surface upon another.

Lagrange's memoirs, two in number, are contained in the "Mémoires de l'Académie des Sciences," of Berlin, for 1779. Lagrange here gives the most general theory of orthomorphic projection consistent with the condition that all parallels and meridians shall be projected in circles.

Gauss's memoir was more general in its nature than that of Lagrange, although he regretted the necessity which he was under of confining himself to the simpler cases of map construction, and expressed the hope that at a future time the investigation would be resumed; but it never was again studied by Gauss, so far as we can judge from his published papers.

Neither of these great mathematicians seems to have given any attention to another phase of the general problem of representing one surface upon another, viz., by actual development deforming the given surface until it coincides with the surface of projection, or surface upon

which it is desired to represent the given surface. The principle of development is the base of many valuable methods of projection, notable among which is the polyconic projection used in the office of the U. S. Coast and Geodetic Survey; these methods are all well known to those who are interested in this subject, so nothing further need be said of them here.

The immediate object of the following very brief paper is to determine the general differential equation of all surfaces which may be developed, or deformed, upon any given surface.

The idea of obtaining such an equation is not new, though I have only seen it referred to in one place, but the following investigation and its results I believe to be quite new.

M. E. Bour wrote a most valuable memoir upon the subject, entitled "Théorie de la déformation des Surfaces," published in the "Journal de l'Ecole Polytechnique," Vol. 22. In the beginning of the paper, however, M. Bour expressly states that he will not give the general solution of the problem, and in fact confines himself to the case where the quantities E and G of the text are $= o$, and also uses the variables

$$x = p + i\,q,$$
$$y = p - i\,q.$$

It is a well-known fact, that, if we have given the equation of any surface in rectangular rectilinear co-ordinates, we may, by means of this equation, express the three co-ordinates of any point of this surface as functions of two independent variable parameters, say p and q; and that, conversely, if the co-ordinates x, y, z are thus expressed as functions of the two parameters, these expressions determine the surface; viz., by elimination of the parameters we obtain the equation $f(x, y, z) = o$ of the surface.

We may, as is customary, of course consider the parameters p and q so determined that the equations of the two sets of lines of curvature shall be

$$\begin{cases} f = \text{const.}, \\ p = \text{const.}, \end{cases} \qquad \begin{cases} f = \text{const.}, \\ q = \text{const.}, \end{cases}$$

that is, we may regard

$$f = \text{const.}, \; p = \text{const.}, \; q = \text{const.}$$

as the equations of these orthogonal surfaces.

The expression for the element of length on the given surface is

1 $$ds^2 = Edp^2 + 2Fd\ pdq + Gdq^2$$

where

$$E = \left(\frac{dx}{dp}\right)^2 + \left(\frac{dy}{dp}\right)^2 + \left(\frac{dz}{dp}\right)^2,$$

2 $$F = \left(\frac{dx}{dp}\ \frac{dx}{dq}\right) + \left(\frac{dy}{dp}\ \frac{dy}{dq}\right) + \left(\frac{dz}{dp}\ \frac{dz}{dq}\right),$$

$$G = \left(\frac{dx}{dq}\right)^2 + \left(\frac{dy}{dq}\right)^2 + \left(\frac{dz}{dq}\right)^2.$$

Now suppose a second surface to exist which is susceptible of development upon the first. Call ξ, η, ζ the co-ordinates of any point and $d\sigma$ the element of length in this case.

If this second surface can be developed upon the first it will be necessary and sufficient that the points of the one be made to correspond to those of the other, that we shall have $ds = d\sigma$ in every direction around two corresponding points.

This equality must hold, then, whatever be the values of dp and dq, which define these different directions.

Now, for $d\sigma$ we have

$$d\sigma^2 = E^1dp_2 + zF^1dp\ dq + G^1dq^2$$

and for $d\sigma = ds$ we must have

$$E = E^1,\ F = F^1,\ G = G^1.$$

It follows from this that the three new variables ξ, η, ζ are three functions of p and q, such that, being substituted for x, y, z in equations 2, these equations shall be identically satisfied.

Conversely, every solution of equations 2 will furnish a surface which may be developed upon the given surface. It is only necessary to eliminate from these equations any two of the quantities x, y, z in order to find the desired equation which will be the resulting differential equation satisfied by the remaining quantity, say by z. We have, now, from the first and third of 2

$$\left(\frac{dx}{dp}\right)^2 + \left(\frac{dy}{dp}\right)^2 = E - \left(\frac{dz}{dp}\right)^2,$$

3

$$\left(\frac{dx}{dq}\right)^2 + \left(\frac{dy}{dq}\right)^2 = G - \left(\frac{dz}{dq}\right)^2.$$

For convenience write

$$a^2 = E - \left(\frac{dz}{dp}\right)^2,$$

4

$$\beta^2 = G - \left(\frac{dz}{dq}\right)^2;$$

then we may replace these two equations by the four

$$\frac{dx}{dp} = \alpha \cos.\theta, \qquad \frac{dx}{dq} = \beta \cos.\varphi,$$

5

$$\frac{dy}{dp} = \alpha \sin.\theta, \qquad \frac{dy}{dq} = \beta \sin.\varphi.$$

The second of 2 now becomes

$$\alpha\beta\,(\cos.\,\theta \cos.\,\varphi + \sin.\,\theta \sin.\,\varphi) = F - \frac{dz}{dp}\frac{dz}{dq} = \gamma\alpha\beta.$$

or

6 $$\text{Cos.}\,(\varphi - \theta) = \gamma.$$

Differentiating the equations of the first row of 5 for q and p, respectively, and subtracting, we eliminate α, the same operations performed upon the second row eliminate y; we have then

$$\frac{d\alpha}{dq}\cos.\theta - \alpha \sin.\theta\,\frac{d\theta}{dq} - \frac{d\beta}{dp}\cos.\theta + \beta \sin.\varphi\,\frac{d\varphi}{dp} = o,$$

7

$$\frac{d\alpha}{dq}\sin.\theta + \alpha \cos.\theta\,\frac{d\theta}{dq} - \frac{d\beta}{dp}\sin.\varphi - \beta \cos.\varphi\,\frac{d\varphi}{dp} = o.$$

Multiply the first of these by cos. θ, the second by sin. θ and add; then multiply the first by cos. φ and the second by sin. φ and add; we have then

$$\frac{d\alpha}{dq} - \frac{d\beta}{dp}\cos.(\varphi - \theta) + \beta\frac{d\varphi}{dp}\sin.(\varphi - \theta) = o,$$

8

$$\frac{d\alpha}{dq}\cos.(\varphi - \theta) + \alpha\frac{d\theta}{dq}\sin.(\varphi - \theta) - \frac{d\beta}{dp} = o,$$

or

$$\text{Sin.}(\varphi - \theta)\frac{d\varphi}{dp} = \frac{1}{\beta}\left[\gamma\frac{d\beta}{dp} - \frac{d\alpha}{dq}\right], = \lambda$$

9

$$\text{Sin.}(\varphi - \theta)\frac{d\theta}{dq} = \frac{1}{\alpha}\left[\frac{d\beta}{dp} - \gamma\frac{d\alpha}{dq}\right], = \mu$$

For brevity we may also write

$$\text{Sin.}(\varphi - \theta) = \tau$$

then, since cos. $(\varphi - \theta) = \gamma$, $\tau^2 = 1 - \gamma^2$. Equations 9 are now written

$$\frac{d\varphi}{dp} = \frac{\lambda}{\tau},$$

10

$$\frac{d\theta}{dq} = \frac{\mu}{\tau}.$$

From the expression cos. $(\varphi - \theta) = \gamma$ we have by differentiation

$$\frac{d\varphi}{dq} = \frac{1}{\tau}\left(\mu - \frac{d\gamma}{dq}\right),$$

11

$$\frac{d\theta}{dp} = \frac{1}{\tau}\left(\lambda - \frac{d\gamma}{dp}\right).$$

Finally, form the expressions for $\frac{d^2\varphi}{dp\,dq}$ from 10 and 11, and equate the results

12 $$\frac{1}{\tau}\frac{d\lambda}{dq} - \frac{\lambda}{\tau^2}\frac{d\tau}{dq} = \frac{1}{\tau}\left(\frac{d\mu}{dp} - \frac{d^2\gamma}{dp\,dq}\right) - \frac{1}{\tau^2}\left(d\mu - \frac{d\gamma}{dq}\right)\frac{d\tau}{dq}.$$

From the relation $1 - \gamma^2 = \tau^2$ we have

$$\tau\frac{d\tau}{dp} = -\gamma\frac{d\gamma}{dp},$$

13

$$\tau\frac{d\tau}{dq} = -\gamma\frac{d\gamma}{dq},$$

Equation 12 now becomes

$$\left(\frac{d\lambda}{dq} - \frac{d\mu}{dp} + \frac{d^2\gamma}{dp\,dq}\right)(1-\gamma^2)$$

14

$$+\gamma\left(\lambda\frac{d\gamma}{dq} - \mu\frac{d\gamma}{dp} + \frac{d\gamma}{dp}\frac{d\gamma}{dq}\right) = 0$$

which contains only E, F, G and the differential coefficients of these quantities and z with respect to p and q, and is consequently the differential equation sought.

Denote now by k the Gaussian measure of curvature given by the expression

15 $$-2V^3k = V^3\left\{\frac{d}{dp}\left[\frac{1}{V}\left(\frac{d\,F}{dq} - \frac{d\,G}{dp}\right)\right] + \frac{d}{dq}\left[\frac{1}{V}\left(\frac{d\,F}{dp} - \frac{d\,E}{dq}\right)\right]\right\}$$
$$- V^3\Gamma,$$

where $V^2 = E\,G - F^2$ and Γ denotes the determinant

$$\begin{vmatrix} E, & G, & F \\ \frac{dE}{dp}, & \frac{dG}{dp}, & \frac{dF}{dp} \\ \frac{dE}{dq}, & \frac{dG}{dq}, & \frac{dF}{dq} \end{vmatrix}$$

Again, denote for brevity the minors of this determinant corresponding to any element by placing that element in brackets, thus,

$$[E] \equiv \frac{dG}{dp}\frac{dF}{dq} - \frac{dG}{dq}\frac{dF}{dp} \text{ etc.};$$

also write

$$A = \frac{dG}{dp} - 2\frac{dF}{dq},$$

$$B = \frac{dE}{dq} - 2\frac{dF}{dp},$$

Substituting now in 14 the values of $\lambda, \mu, \tau, \gamma, \alpha, \beta$ we find, after some rather tedious but not difficult reductions, the following form for this equation

$$4V^2(rt-s^2)+\left\{4G\sqrt{G}\left(\frac{d\sqrt{G}}{dp}-\frac{d\ F}{dq\sqrt{G}}\right)\frac{dz}{dp}-\left(E\frac{dG}{dq}+A\ F\right)\frac{dz}{dq}\right\}r$$

$$+4\left(G\frac{dE}{dq}\frac{dz}{dp}+E\frac{dG}{dp}\frac{dz}{dq}\right)s+\left\{4E\sqrt{E}\left(\frac{d\sqrt{E}}{dq}-\frac{d}{dp}\frac{F}{\sqrt{E}}\right)\frac{dz}{dq}-\left(G\frac{dE}{dp}+BF\right)\frac{dz}{dp}\right\}t$$

16 $$+\left\{2\sqrt{G}\left[\frac{d}{d}\sqrt{G}\frac{dE}{dq}-G\frac{d}{dp}\frac{A}{\sqrt{G}}\right]+2[E]\right\}\left(\frac{dz}{dp}\right)^2$$

$$+\left\{F\sqrt{F}\left[\frac{d}{dp}\frac{4A}{\sqrt{F}}+\frac{d}{dq}\frac{4}{\sqrt{F}}\frac{dE}{dq}\right]+2[F]\right\}\frac{dz}{dp}\frac{dz}{dq}$$

$$+\left\{2\sqrt{E}\left[\frac{d}{dp}\sqrt{E}\frac{dG}{dp}-E\frac{d}{dq}\frac{B}{\sqrt{E}}+2[G]\right\}\left(\frac{dz}{dq}\right)^2-2V^4k=0\right.$$

where r, s, t denote respectively the second derivatives

$$\frac{d^2z}{dp^2}, \quad \frac{d^2z}{dpdq}, \quad \frac{d^2z}{dq^2}.$$

It is to be observed that this equation is linear in $(rs-t^2)$ and in r, s

and t, and is in fact a partial differential equation of the second order of the form

$$Rr+Ss+Tt+V(rs-t^2)=W,$$

when R, S, T, V and W are given functions of x, y, z, $\frac{dz}{dp}$, $\frac{dz}{dq}$ or of p, q, $\frac{dz}{dp}$, $\frac{dz}{dq}$. A general integration is of course impossible, so we will note only a few special cases. If we consider now that the three surfaces f, p, q are orthogonal, then the curves given briefly as $p=$ const. $q=$ const. cut at right angles, since they belong to the two different lines of curvature, and for this case $F=o$ and equation 16 takes the form

$$17\quad 4EG(rt-s^2)+\left(\frac{d.G^2}{dp}\frac{dz}{dp}-E\frac{dG}{dq}\frac{dz}{dq}\right)r+4\left(G\frac{d\,E}{dq}\frac{dz}{dp}+E\frac{dG}{dp}\frac{dz}{dq}\right)s$$
$$+\left(\frac{d.E^2}{dq}\frac{dz}{dq}-G\frac{dE}{dp}\frac{dz}{dp}\right)t+2\sqrt{G}\left[\frac{d}{dq}\sqrt{G}\frac{dE}{dq}-G\frac{d}{dq}\frac{1}{\sqrt{G}}\frac{dG}{dp}\right]\left(\frac{dz}{dp}\right)^2$$
$$+[F]\frac{dz}{dp}\frac{dz}{dq}+2\sqrt{E}\left[\frac{d}{dp}\sqrt{E}\frac{dG}{dp}-E\frac{d}{dp}\frac{1}{\sqrt{E}}\frac{dE}{dq}\right]\left(\frac{dz}{dq}\right)^2-2E^2G^2k_0=o$$

where

$$k_0=-\tfrac{1}{2}\left\{\frac{d}{dp}\frac{1}{\sqrt{E\,G}}\frac{dG}{dp}-\frac{d}{dq}\frac{1}{\sqrt{E\,G}}\frac{dE}{dq}\right\}$$

For $E=G$ this becomes

$$18\quad 4E^2(rt-s^2)+\frac{d.E^2}{dp}\left[\frac{dz}{dp}(r-\tfrac{1}{2}t)+2\frac{dz}{dq}s\right]+\frac{d.E^2}{dq}\left[\frac{dz}{dq}(t-\tfrac{1}{2}r)+2\frac{dz}{dp}s\right]+$$
$$\left\{\tfrac{1}{2}\frac{d^2E^2}{dq^2}+E\frac{d^2E}{dq^2}+E^2\frac{d^2\log.E}{dp^2}\right\}\left(\frac{dz}{dp}\right)^2+\left\{\tfrac{1}{2}\frac{d^2E^2}{dp^2}+E\frac{d^2E}{dp^2}-E^2\frac{d^2\log.E}{dq^2}\right\}\left(\frac{dz}{dq}\right)^2-2E^4\left(\frac{d^2}{dp^2}-\frac{d^2}{dq^2}\right)\log.E=o.$$

Suppose in equation 16 that $E=G=o$: this requires that the quantities denoted by α and β shall be imaginary—or

$$\alpha=i\,\alpha^1\quad\beta=i\,\beta^1,$$

it would be convenient in starting from this hypothesis to use the imaginary variables already defined as

$$x=p+i\,q,$$
$$y=p+i\,q,$$

however it is not the intention to dwell on this point as Bour's memoir treats the case so fully. The form which the general differential equation assumes in this case is, however, noteworthy. Assume $F = 2\,\Phi$, then we have

$$(rt-s^2) - \frac{1}{\Phi}\frac{d\Phi}{dq}\frac{dz}{dq}r - \frac{1}{\Phi}\frac{d\Phi}{dp}\frac{dz}{dp}t$$

$$19 \quad + \left[2\frac{1}{\Phi}\left(\frac{d^2\Phi}{dp\,dq} - \frac{1}{\Phi}\frac{d\Phi}{dp}\frac{d\Phi}{dq}\right)\right]\frac{dz}{dp}\frac{dz}{dq} + 2\left[\frac{1}{\Phi}\frac{d\Phi}{dp}\frac{d\Phi}{dq} - \frac{d^2\Phi}{dp\,dq}\right]$$

$$= o\,;$$

add and subtract

$$\frac{1}{\Phi^2}\frac{d\Phi}{dp}\frac{d\Phi}{dq}\frac{dz}{dp}\frac{dz}{dq}$$

and this becomes readily

$$2\left(\frac{dz}{dp}\frac{dz}{dq} - \Phi\right)\frac{d^2\log.\,\Phi}{dp\,dq} - s^2$$

$$20 \quad + \left(r - \frac{dz}{dp}\frac{d\log.\,\Phi}{dp}\right)\left(t - \frac{dz}{dq}\frac{d\log.\,\Phi}{dq}\right) = o.$$

Make in this equation

$$\frac{dz}{dp}\frac{dz}{dq} = \Phi$$

and we find that the equation is satisfied, therefore

$$\frac{dz}{dp}\frac{dz}{dq} = \Phi$$

is a singular solution of the differential equation.

If we make $E = 1$, $F = o$ and G a function of p only, we come to the case of the development upon surfaces of revolution, a particular case of which has been studied by Weingarten in Vol. 59 of "Crelle's Journal." There are several other suppositions which might be made, and which would conduct to interesting results, but the object of the investigation has been attained, and so I leave the subject here. I think it quite possible that a singular solution might be found for equation 16 (or equation 17, which is a sufficiently general form), which would prove valuable in studying the general geometric proportions of this class of surfaces.

It is to be observed that for E, F, G constant (including the case of $F = o$) 16 reduces to

$$rt - s^2 = o$$

the simplest class of developable surfaces, viz., those which can be developed upon a plane.

Washington, D. C., August 24, 1879.

FUTURE WATER SUPPLY OF PHILADELPHIA.

By Henry P. M. Birkinbine, M. E.

Read before the Franklin Institute at its meeting October 15th, 1879.

I have had the honor of reading two papers before the Institute upon the "Future Water Supply of Philadelphia."* In the first paper some of the available sources were examined: the Schuylkill, Delaware and the Perkiomen; their volume and the present and prospective comparative purity of the water compared. In the second paper the means now used and those proposed for securing a supply from these sources were presented and analyzed.

It was, no doubt, evident to those who heard these papers, or who have read them, that one object in presenting them before the Institute was to demonstrate the practicability and desirableness of securing a supply of water for the city of Philadelphia from the Perkiomen by gravitation, a project reported upon and recommended to the Councils of Philadelphia in 1866.

I have been requested to read another paper upon this important subject. The request has, no doubt, been prompted by the interest created by several articles in the daily papers and the able article upon the "Future Water Supply of Philadelphia," by James F. Smith, C.E., in the last number of the Journal (October).

After waiting so many years it is a source of gratification to have the public endorsement of this project by an engineer of the standing and long experience of James F. Smith, C. E., whose duties as the engineer of the Schuylkill Navigation Company have made him personally acquainted with this particular region and with the storage and supply of water from streams in the drainage area of the Schuylkill.

While the Commission of Engineers, appointed in 1875 to report upon a better supply of water for Philadelphia, gave the Perkiomen gravity plan their unanimous approval, they suggested so many other plans that it is hard to decide what they did or meant to recommend by their report.

I fully acknowledge my obligations to Mr. Smith personally, and as

* See Journal of the Franklin Institute for May and July, 1878.

a citizen of Philadelphia, for the great amount of care and attention he has bestowed upon the consideration of this important subject, and the valuable information given to the public in his article. Statements made by an engineer of his standing and experience will be accepted without question, as they should be; and yet there may be facts in connection with the subject which have not come under his notice, or conclusions, based upon the representations of others, which may be incorrect. It is for the purpose of making some explanations and adding a few additional facts that this paper is presented for your consideration.

In the water supply of a city the head under which the water should be furnished, and the quantity required, are among the most important points to be settled, and this should be done before any work is undertaken. These questions are readily answered by asserting that the greater the head or pressure and the larger the volume the better. This is true in the main, but there are circumstances and conditions which modify and restrict both of these essentials to a practical limit, and the proper head and quantity become, therefore, important subjects of inquiry.

The head or pressure of the Fairmount reservoirs is but 96 feet above city datum, 54 feet above the highest and 84 feet above the lowest grade of the streets, and as these furnish the most densely populated and the business centres of the city, an augmented head would be of great advantage.

After a careful examination of the entire area covered by the city it was found that a reservoir at an elevation of 170 feet would command almost the whole area, and that the parts lying at a greater altitude would necessitate another system of about double this elevation, leaving a few small districts demanding a still greater height. It was therefore decided that a supply furnished at an elevation of 180 feet would meet the requirements of the city better than any other head. This pressure or force would not be too great for the old pipe system and would be sufficient to reach the upper stories of the larger buildings, and would give a more satisfactory supply through the fire hydrants. This being settled, the next question was, how large a supply must be provided to meet the prospective demands of the city—a more difficult one to answer, as no one can predict what the future of this city may be—and if, as some assert, it is destined to become the London of this continent, and its inhabitants counted by millions, it would

require corresponding works. It was thought better to forecast the future by the history of the past. In 1865 it was found that the demand for water had more than doubled in ten years, and was then an average of over 30 million gallons per day; from this it is estimated that 150 million gallons per day would furnish an ample supply for the increase at that rate for at least 25 years, or until the city numbers between two and three million inhabitants. But this rapid increase will scarcely be realized, and it is probable that the above quantity (150,000,000 gallons) will furnish a copious supply for the next half of a century. The increase in the number of gallons of water supplied in 1875, as compared with 1865, was nearly 37 per cent. The amount supplied for the year 1878 was an average of nearly 53,000,000 gallons per day. These two factors were then adopted as a basis, and the surveys and examinations made for the purpose of securing a minimum supply of 150 million gallons per day, delivered into a reservoir in the city at an elevation not less than 170 feet above city datum. Surveys were made of all the streams of any importance within thirty miles of the city. The Delaware River was also examined as far up as the Water Gap.

The Perkiomen was found to possess all the requirements of quantity and elevation, and, so far as present and prospective comparative purity of the water, it was equaled by none of the other sources examined. This stream was, therefore, recommended.

A most desirable location was found for an impounding reservoir, not at as great an elevation as desired; but the location admits of the construction of a dam of almost any height. As it is neither necessary nor desirable that the inlet of the aqueduct should be placed at or near the bottom, it was only intended to draw the water for the city from the upper part of the dam, leaving the lower part for the accumulation of suspended matter brought into the reservoir with the water.

Surveys were made for the purpose of ascertaining if the minimum head, 170 feet, could be secured, and it was found that by raising the water by impounding 65 feet, the surface would be 204 feet above city datum, and cover 1500 acres. This would give ample head to overcome friction of the aqueduct, and allow the dam to be drawn down from 12 to 15 feet.

The bottom of the Croton aqueduct at the gate chamber is but 11·4 feet below the surface of the dam, and the Loch Katrine aqueduct

draws the lake down seven feet below its overflow. The height of the proposed dam need not be restricted to 65 feet; it can be made 100 feet deep, or deeper, if necessary.

It is to be regretted that no surveys have been made which would enable the actual location of a line of aqueduct, but from some little preliminary work and an examination of the country between the Perkiomen and the city, lines of aqueduct at the proposed elevation are practicable by several routes.

Being confident that the Perkiomen would be the source, and gravitation the mode of supply, at some time in the future, a reservoir was located in the 24th ward, George's Hill, north of the present reservoir, and was placed at an elevation of 180 feet, to form a part of this system of supply. This was to have been constructed by shutting up the end of the ravine along Belmont avenue, thus forming an artificial lake which would have stored 225 million gallons and cost but one-half as much as the reservoir built in its stead, which stores but 30 million gallons. It is true, the surface of the water in the present basin is 32 feet higher than the one proposed and commenced would have been. This greater elevation commands but a very small additional area, and is not of sufficient altitude for the high lying portions of this district. The change in location has not only given the city a much smaller reservoir, at a largely increased cost, but entails an annual expense for pumping the water to an unnecessary height, which in 1878 amounted to $7,121.46.

This, then, is what was supposed or intended to be done by the Perkiomen project:

Objections Answered.

Mr. Smith's objections to the original site selected for the construction of the impounding reservoir are, first, as follows: "It will be observed the conduit from the lake was not designed to deliver water into the receiving basin in the city at a greater elevation than 133 feet above city datum." This conclusion is arrived at from statements in the report of the Commission of Engineers; but it has been demonstrated by actual surveys that a dam of but 65 feet in depth would deliver water by gravitation into a reservoir in the city 170 feet above city datum, and allow the water in the proposed lake to be drawn down 12 feet. These facts have never been controverted, and the Commission of Engineers used the same figures; therefore it is evident that they proposed to loose 47 feet in the declivity or fall of

the conduit to the city; an unnecessary head, as Mr. Smith's calculations demonstrate. He estimates a loss of 25·94 feet in the entire length of his proposed conduit, or 0·94 feet per mile. The fall in the Croton aqueduct, New York, is from 0·504 to 1·106 feet per mile. The fall in Cochituate aqueduct, Boston, is but 0·45 feet per mile, including the pipe conduit; in Loch Katrine aqueduct it is 0·833 feet per mile, and in the Washington aqueduct 0·792 feet to the mile. I proposed to use a fall of 20 feet, or 0·727 feet per mile, in bringing in the water of the Perkiomen.

From the above it is evident that the first location has sufficient elevation, and it was designed to supply all the reservoirs in the city with the exception of the Roxborough and Mt. Airy, which have an altitude of 365 feet. This location was also selected by the Commission of Engineers, who proposed a dam ten feet deeper than the surveys for the minimum proved to be necessary.

An inspection of the contour map prepared by the Water Department shows that a reservoir with the water surface 180 feet above city datum will practically supply the entire city, so that the proposed additional head of 60 feet will be of little actual value, as it would only supply a narrow strip, lying between an elevation of 130 and 190 feet, not three square miles in area. This additional pressure would make it necessary to empty 95 per cent. of the water into and supply it from reservoirs of less elevation, as the head on the low lying districts would be unmanageable and destructive to the old pipe systems.

The reservoirs known as the Schuylkill, Delaware, and Corinthian avenue, when considered as a part of the water supply of a great city, are of little importance on account of their limited storage capacity. The ground they occupy, and the increased value their removal would give to the property in their immediate vicinity, would go far towards paying for a reservoir of ample capacity at a proper elevation. These should therefore not stand in the way of an arrangement which would place practically the entire city under one system of supply. If it has been demonstrated that the location for the dam on the main stream of the Perkiomen above Schwencksville has a sufficient head, then the objections on that account may be considered as answered.

The second objection is "the great length of the mound dam." When you are informed that a dam 1100 feet long on the top will raise the water 65 feet and cover 1500 acres, and that the storage capa-

city of the first 12 feet below the overflow would be 5,000,000,000 gallons, and that the foundations and abutments of the dam will be of solid rock, you will see that it will be difficult to find a more desirable location. That suggested by Mr. Smith was examined for a supplementary or feeding reservoir when the demands of the city would make one necessary.

The third objection "is the value of the property submerged and expense of removing the railroad." When my surveys and recommendations were made no railroad existed in the valley. The surveys for a railroad were not made until after mine were completed. This is therefore not a question of engineering, but is simply one of comparative cost, and can only be settled when the value of the property overflowed, and the cost of the several dams which are proposed to take the place of the large one, and the increased length of the aqueduct, at least 4½ miles, have been ascertained; then it will probably be demonstrated that the original location would be the less costly, and it certainly is the most desirable. To carry an aqueduct at the proposed greater elevation would add much to its cost of construction and also to its length.

Points Settled.

The following important facts in regard to the Perkiomen plan may be claimed as demonstrated:

1st. The comparative purity and desirableness of the water. All who have examined it agree that in this most essential requisite it is now and likely to remain entirely satisfactory.

2d. That there is an abundant supply of water. Mr. McAlpine, one of the Commission of Engineers, estimated the daily average flow of the stream at 331,000,000 gallons. Mr. Smith, by adding the East branch, Indian Run and Towamencin Creek, estimates the daily average flow 272,265,752 gallons. His estimate leaves out six miles of the main valley.

Calculations based upon data in the "Report of the Park Commission" gives the daily average flow, at the point of the original location of the dam, 250,000,000 gallons.

My estimate was 240,000,000 gallons per day, without taking into account the East branch, Skippack, Towamencin, the Wissahickon or or any other stream the waters of which could be brought into the conduit on its way to the city.

There can, therefore, be no question but that from 150,000,000 to

175,000,000 gallons can be secured for a supply for the city after making all deductions for evaporation, soakage and waste of storm water; an abundant supply of water for a city of more than double the inhabitants Philadelphia now contains, with enough to supply the towns near which the line of aqueduct would pass, and sufficient for the city of Camden, should it desire to be supplied from this source.

3d. There is sufficient elevation to furnish all the city with water by gravitation from the first location, with but trifling exceptions, not amounting to over three per cent. of all the water required.

The strange indifference of the public in reference to this project, and the unwillingness of the municipal authorities to investigate it, make its advocacy embarrassing and almost hazardous to the reputation of an engineer; but after the unanimous endorsement of the Commission of Engineers and the pains taken by one of them, the most experienced in water works construction—William J. McAlpine—to present it somewhat in detail, with general plans and estimates, and the endorsement, after a thorough examination of the subject, by Mr. James F. Smith, C. E., may we not hope that the project will at least be thoroughly investigated by our municipal authorities?

Efforts to interest leading men in the city government have been met with the reply of "What is the use of talking about it? the city cannot increase its indebtedness or undertake any enterprise of such magnitude." Yet since the Perkiomen project has been before Councils over five millions of dollars has been expended upon the enlargement of the water works. Some of this money has been worse than thrown away, and to-day the supply of water to the city is not as full, when the number of inhabitants is taken into account. Very few of the extensions are of such a character as to be of a permanent nature, and are only sufficient to meet the pressing necessities of the present demands. Such appears to be the policy for the future, and it will be necessary to make large appropriations almost every year for extensions.

A supply flowing into the city by gravitation would also save $150,000 per annum in cost of operating the works. It is therefore evident that the city can save nothing by pursuing its present policy in relation to its water supply. Works of the proposed character and capacity when completed will require no further expenditures for many years to come, and allow the burdened tax-payer rest, so far as

the demand for water works extension is concerned, for a generation or more.

The cross sections of the different aqueducts are:

BOSTON, COCHITUATE.—Brick conduit, oviform, 6 feet 4 inches by 5 feet. 14·627 miles long. Total fall, 3·74 feet.

MYSTIC POND.—Brick conduit, oviform, 5 feet by 5 feet 8 inches. 3000 feet long. Fall, 0·5 foot per mile.

SUDBURY RIVER.—7 feet 8 inches by 9 feet; 16 miles long; capacity, 70 million gallons per day; fall, 1·055 feet per mile.

NEW YORK, CROTON.—7 feet 5 inches by 8 feet 5½ inches; length, 38 miles; fall, 0·504 to 1·106 feet per mile.

BALTIMORE. *Old Aqueduct.*—Same as Cochituate; fall, 1 foot per mile; flow, 30,000,000 gallons per day; 4¾ miles long. *New Aqueduct.*—12 feet diameter, 7 miles long; fall, one foot per mile; capacity, 170 million gallons per day.

WASHINGTON.—9 feet diameter, 11½ miles long, fall, 0·792 feet per mile; capacity, 67 million gallons per day.

Using Robert K. Martin's formula, incorrectly printed in the JOURNAL of October, page 244,

$$V = \sqrt{\frac{180 \times \text{head in feet} \times \text{diameter in inches}}{\text{Length in feet.}}}$$

An aqueduct from the Perkiomen to the city, 26 miles long, 14 feet diameter, with a fall of 20 feet, will discharge 200 million gallons per day.

Limits of the Animal and Vegetable Kingdoms.—Prof. Stein, in his beautiful work on the flagellate Infusoria, distinguishes the lowest animals from vegetables by the simultaneous presence of vibratile cilia, contractile cavities and a nucleus. Protozoans have all three of these organs, but he thinks this cannot be said of any vegetable. E. Maupas shows that the zoospores of two Algæ, the *Microspora floccosa* and an unclassified *Oedogonium*, have well-marked nuclei, together with the cilia and contractile cavity, and concludes that neither physiology nor morphology furnishes any criterion for distinguishing animals from vegetables. Claude Bernard has established the biological unity of all living organisms, and Protozoans aud Protophytes can only be classified by means of their tendencies and affinities.—*Comptes Rendus.* C.

ON RADIANT MATTER.

A Lecture delivered to the British Association for the Advancement of Science, at Sheffield, Friday, August 22d, 1879.

By WILLIAM CROOKES, F. R. S.

To throw light on the title of this lecture I must go back more than sixty years—to 1816. Faraday, then a mere student and ardent experimentalist, was 24 years old, and at this early period of his career he delivered a series of lectures on the General Properties of Matter, and one of them bore the remarkable title, *On Radiant Matter*. The great philosopher's notes of this lecture are to be found in Dr. Bence Jones's "Life and Letters of Faraday," and I will here quote a passage in which he first employs the expression *Radiant Matter*:—

"If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall perhaps, if we can form any conception at all, not fall far short of Radiant Matter; and as in the last conversion many qualities were lost, so here also many more would disappear."

Faraday was evidently engrossed with this far-reaching speculation, for three years later—in 1819—we find him bringing fresh evidence and argument to strengthen his startling hypothesis. His notes are now more extended, and they show that in the intervening three years he had thought much and deeply on this higher form of matter. He first points out that matter may be classed into four states—solid, liquid, gaseous and radiant—these modifications depending upon differences in their several essential properties. He admits that the existence of Radiant Matter is as yet unproved, and then proceeds, in a series of ingenious analogical arguments, to show the probability of its existence.*

* "I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sanguine philosopher, a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned.

"As we ascend from the solid to the fluid and gaseous states, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids, all the varieties of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed.

If, in the beginning of this century, we had asked, What is a gas? the answer then would have been that it is matter, expanded and rarefied to such an extent as to be impalpable, save when set in violent motion; invisible, incapable of assuming or of being reduced into any definite form like solids, or of forming drops like liquids; always ready to expand where no resistance is offered, and to contract on being subjected to pressure. Sixty years ago such were the chief attributes assigned to gases. Modern research, however, has greatly enlarged and modified our views on the constitution of these elastic fluids. Gases are now considered to be composed of an almost infinite number of small particles or molecules, which are constantly moving in every direction with velocities of all conceivable magnitudes. As these molecules are exceedingly numerous, it follows that no molecule can move far in any direction without coming in contact with some other molecule. But if we exhaust the air or gas contained in a closed vessel, the number of molecules become diminished, and the distance through which any one of them can move without coming in contact with another is increased, the length of the mean free path being inversely proportional to the number of molecules present. The further this process is carried the longer becomes the average distance a molecule can travel before entering into collision; or, in other words, the longer its mean free path, the more the physical properties of the gas or air are modified. Thus, at a certain point, the phenomena of the radiometer become possible, and on pushing the rarefaction still further,

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Opacity and color frequently give way to a colorless transparency, and a general mobility of particles is conferred.

"Passing onward to the gaseous, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in color that were left, are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, color, elasticity and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades of color.

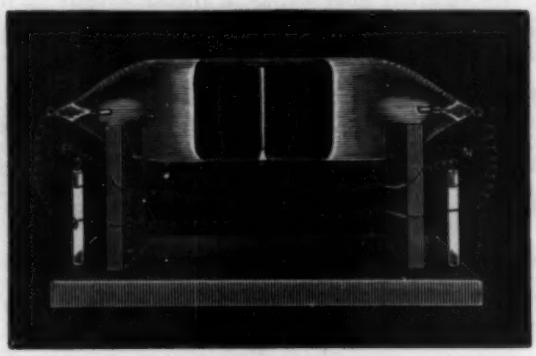
"To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favor. These persons show you a gradual resignation of properties in the matter we can appreciate as the matter ascends in the scale of forms, and they would be surprised if that effect were to cease at the gaseous state. They point out the greater exertions which Nature makes at each step of the change, and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form."—*Life and Letters of Faraday*, vol 1, p. 308.

i. e. decreasing the number of molecules in a given space and lengthening their mean free path, the experimental results are obtainable to which I am now about to call your attention. So distinct are these phenomena from anything which occurs in air or gas at the ordinary tension, that we are led to assume that we are here brought face to face with Matter in a Fourth state or condition, a condition as far removed from the state of gas as a gas is from a liquid.

Mean Free Path. Radiant Matter.

I have long believed that a well-known appearance observed in vacuum tubes is closely related to the phenomena of the mean free path of the molecules. When the negative pole is examined while the discharge from an induction-coil is passing through an exhausted tube, a dark space is seen to surround it. This dark space is found to increase

Fig. 1.



and diminish as the vacuum is varied, in the same way that the mean free path of the molecules lengthens and contracts. As the one is perceived by the mind's eye to get greater, so the other is seen by the bodily eye to increase in size; and if the vacuum is insufficient to permit much play of the molecules before they enter into collision, the passage of electricity shows that the "dark space" has shrunk to small dimensions. We naturally infer that the dark space is the mean free path of the molecules of the residual gas, an inference confirmed by experiment.

I will endeavor to render this "dark space" visible to all present. Here is a tube (Fig. 1), having a pole in the centre in the form of a metal disk, and other poles at each end. The centre pole is made

negative, and the two end poles connected together are made the positive terminal. The dark space will be in the centre. When the exhaustion is not very great the dark space extends only a little on each side of the negative pole in the centre. When the exhaustion is good, as in the tube before you, and I turn on the coil, the dark space is seen to extend for about an inch on each side of the pole.

Here, then, we see the induction spark actually illuminating the lines of molecular pressure caused by the excitement of the negative pole. The thickness of this dark space is the measure of the mean free path between successive collisions of the molecules of the residual gas. The extra velocity with which the negatively electrified molecules rebound from the excited pole keeps back the more slowly moving molecules which are advancing toward that pole. A conflict occurs at the boundary of the dark space, where the luminous margin bears witness to the energy of the discharge.

Therefore the residual gas—or, as I prefer to call it, the gaseous residue—within the dark space is an entirely different state to that of the residual gas in vessels at a lower degree of exhaustion. To quote the words of our last year's President, in his Address at Dublin:—

"In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure."

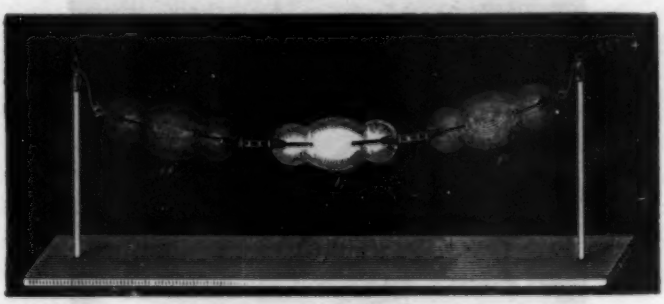
In the vessels with the lower degree of exhaustion, the length of the mean free path of the molecules is exceedingly small as compared with the dimensions of the bulb, and the properties belonging to the ordinary gaseous state of matter, depending upon constant collisions, can be observed. But in the phenomena now about to be examined, so high is the exhaustion carried that the dark space around the negative pole has widened out till it entirely fills the tube. By great rarefaction the mean free path has become so long that the hits in a given time in comparison to the misses may be disregarded, and the average molecule is now allowed to obey its own motions or laws without interference. The mean free path, in fact, is comparable to the dimensions of the vessel, and we have no longer to deal with a *continuous* portion of matter, as would be the case were the tubes less highly exhausted, but we must here contemplate the molecules *individually*. In these highly exhausted vessels the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and radiating from

the pole with enormous velocity, they assume properties so novel and so characteristic as to entirely justify the application of the term borrowed from Faraday, that of *Radiant Matter*.

Radiant Matter exerts Powerful Phosphorogenic Action where it strikes.

I have mentioned that the Radiant Matter within the dark space excites luminosity where its velocity is arrested by residual gas outside the dark space. But if no residual gas is left, the molecules will have their velocity arrested by the sides of the glass; and here we come to the first and one of the most noteworthy properties of Radiant Matter discharged from the negative pole—its power of exciting phosphorescence when it strikes against solid matter. The number of bodies

Fig. 2.



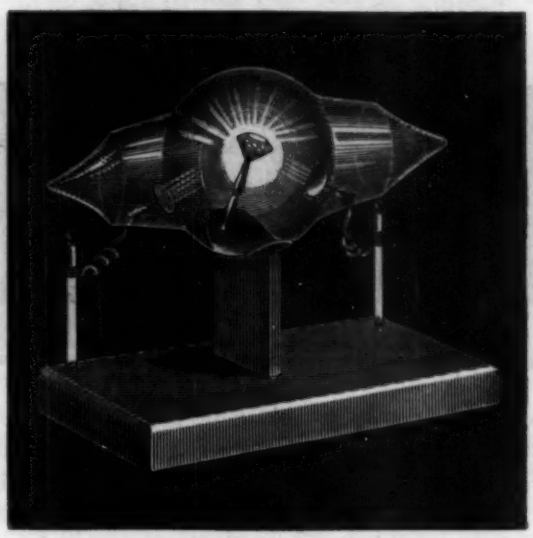
which respond luminously to this molecular bombardment is very great, and the resulting colors are of every variety. Glass, for instance, is highly phosphorescent when exposed to a stream of Radiant Matter. Here (Fig. 2) are three bulbs composed of different glass; one is uranium glass (*a*), which phosphoresces of a dark green color; another is English glass (*b*), which phosphoresces of a blue color; and the third (*c*) is soft German glass—of which most of the apparatus before you is made—which phosphoresces of a bright apple green.

My earlier experiments were almost entirely carried on by the aid of the phosphorescence that glass takes up when it is under the influence of the radiant discharge; but many other substances possess this phosphorescent power in a still higher degree than glass. For instance, here is some of the luminous sulphide of calcium prepared according to M. Ed. Becquerel's description. When the sulphide is exposed to

light—even candlelight—it phosphoresces for hours with a bluish white color. It is, however, much more strongly phosphorescent to the molecular discharge in a good vacuum, as you will see when I pass the discharge through this tube.

Other substances besides English, German, and uranium glass, and Becquerel's luminous sulphides, are also phosphorescent. The rare mineral phenacite (aluminate of glucinum) phosphoresces blue; the mineral spodumene (a silicate of aluminium and lithium) phosphoresces a rich golden yellow; the emerald gives out a crimson light. But without exception, the diamond is the most sensitive substance I have yet met for ready and brilliant phosphorescence. Here is a very

Fig. 3.

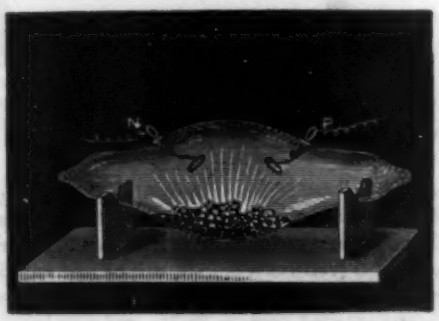


curious fluorescent diamond, green by daylight, colorless by candlelight. It is mounted in the centre of an exhausted bulb (Fig. 3), and the molecular discharge will be directed on it from below upward. On darkening the room you see the diamond shines with as much light as a candle, phosphorescing of a bright green.

Next to the diamond the ruby is one of the most remarkable stones for phosphorescing. In this tube (Fig. 4) is a fine collection of ruby pebbles. As soon as the induction spark is turned on you will see these rubies shining with a brilliant rich red tone, as if they were glowing hot. It

scarcely matters what color the ruby is, to begin with. In this tube of natural rubies there are stones of all colors—the deep red and also the pale pink ruby. There are some so pale as to be almost colorless, and some of the highly-prized tint of pigeon's blood; but under the impact of Radiant Matter they all phosphoresce with about the same color.

Fig. 4.



Now the ruby is nothing but crystallized alumina with a little coloring matter. In a paper by Ed. Becquerel,* published twenty years ago, he describes the appearance of alumina as glowing with a rich red color in the phosphoroscope. Here is some precipitated alumina prepared in the most careful manner. It has been heated to whiteness, and you see it also glows under the molecular discharge with the same rich red color.

The spectrum of the red light emitted by these varieties of alumina is the same as described by Becquerel twenty years ago. There is one intense red line, a little below the fixed line B in the spectrum, having a wave-length of about 6895. There is a continuous spectrum beginning at about B, and a few fainter lines beyond it, but they are so faint in comparison with this red line that they may be neglected. This line is easily seen by examining with a small pocket spectroscope the light reflected from a good ruby.

There is one particular degree of exhaustion more favorable than any other for the development of the properties of Radiant Matter which are now under examination. Roughly speaking it may be put at the millionth of an atmosphere.† At this degree of exhaustion the

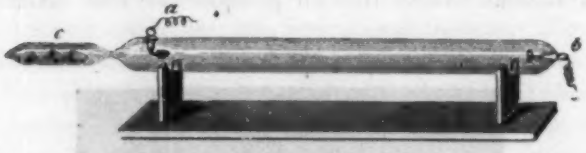
* Annales de Chimie et de Physique, 3d series, vol. lvii, p. 50, 1859.

† 1·0 millionth of an atmosphere = 0·00076 millim.
1315·789 millionths of an atmosphere = 1·0 millim.
1,000,000 " " " = 760·0 millims.
" " " " = 1 atmosphere.

phosphorescence is very strong, and after that it begins to diminish until the spark refuses to pass.*

I have here a tube (Fig. 5) which will serve to illustrate the depen-

Fig. 5.



dence of the phosphorescence of the glass on the degree of exhaustion. The two poles are at *a* and *b*, and at the end (*c*) is a small supplementary

*Nearly 100 years ago Mr. Wm. Morgan communicated to the Royal Society a Paper entitled "Electrical Experiments made to ascertain the Non-conducting Power of a Perfect Vacuum, etc." The following extracts from this Paper, which was published in the Phil. Trans. for 1785 (vol. lxxv, p. 272), will be read with interest:

"A mercurial gage about fifteen inches long, carefully and accurately boiled till every particle of air was expelled from the inside, was coated with tin-foil five inches down from its sealed end, and being inverted into mercury through a perforation in the brass cap which covered the mouth of the cistern; the whole was cemented together, and the air was exhausted from the inside of the cistern through a valve in the brass cap, which producing a perfect vacuum in the gage formed an instrument peculiarly well adapted for experiments of this kind. Things being thus adjusted (a small wire having been previously fixed on the inside of the cistern to form a communication between the brass cap and the mercury, into which the gage was inverted) the coated end was applied to the conductor of an electrical machine, and notwithstanding every effort, neither the smallest ray of light, nor the slightest charge, could ever be procured in this exhausted gage."

"If the mercury in the gage be imperfectly boiled, the experiment will not succeed; but the color of the electric light, which in air rarefied by an exhauster is always violet or purple, appears in this case of a beautiful green, and, what is very curious, the degree of the air's rarefaction may be nearly determined by this means; for I have known instances, during the course of these experiments, where a small particle of air having found its way into the tube, the electric light became visible, and as usual of a green color; but the charge being often repeated, the gage has at length cracked at its sealed end, and in consequence the external air, by being admitted into the inside, has gradually produced a change in the electric light from green to blue, from blue to indigo, and so on to violet and purple, till the medium has at length become so dense as no longer to be a conductor of electricity. I think there can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum."

"This seems to prove that there is a limit even in the rarefaction of air, which sets bounds to its conducting power; or, in other words, that the particles of air may be so far separated from each other as no longer to be able to transmit the electric fluid; that if they were brought within a certain distance of each other, their conducting power begins, and continually increases till their approach also arrives at its limit."

tube connected with the other by a narrow aperture, and containing solid caustic potash. The tube has been exhausted to a very high point, and the potash treated so as to drive off moisture and injure the vacuum. Exhaustion has then been re-commenced, and the alternate heating and exhaustion repeated until the tube has been brought to the state in which it now appears before you. When the induction spark is first turned on nothing is visible—the vacuum is so high that the tube is non-conducting. I now warm the potash slightly and liberate a trace of aqueous vapor. Instantly conduction commences, and the green phosphorescence flashes out along the length of the tube. I continue the heat, so as to drive off more gas from the potash. The green gets fainter, and now a wave of cloudy luminosity sweeps over the tube, and stratifications appear, which rapidly get narrower, until the spark passes along the tube in the form of a narrow purple line. I take the lamp away, and allow the potash to cool; as it cools, the aqueous vapor, which the heat had driven off, is re-absorbed. The purple line broadens out, and breaks up into fine stratifications; these get wider, and travel toward the potash tube. Now a wave of green light appears on the glass at the other end, sweeping on and driving the last pale stratification into the potash; and now the tube glows over its whole length with the green phosphorescence. I might keep it before you, and show the green growing fainter and the vacuum becoming non-conducting; but I should detain you too long, as time is required for the absorption of the last traces of vapor by the potash, and I must pass on to the next subject.

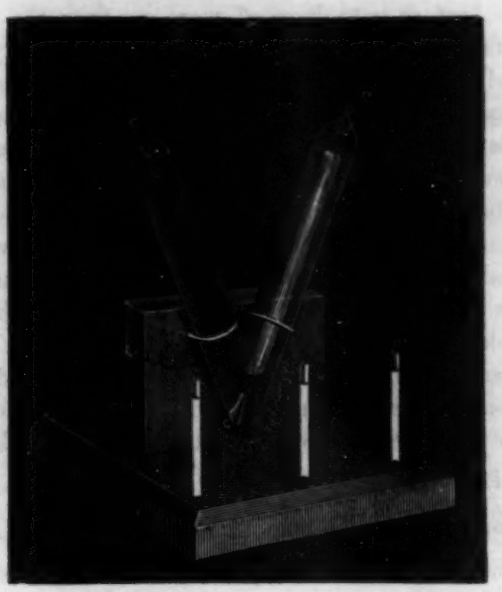
Radiant Matter proceeds in Straight Lines.

The Radiant Matter, whose impact on the glass causes an evolution of light, absolutely refuses to turn a corner. Here is a V-shaped tube (Fig. 6), a pole being at each extremity. The pole at the right side being negative, you see that the whole of the right arm is flooded with green light, but at the bottom it stops sharply and will not turn the corner to get into the left side. When I reverse the current and make the left pole negative, the green changes to the left side, always following the negative pole and leaving the positive side with scarcely any luminosity.

In the ordinary phenomena exhibited by vacuum tubes—phenomena with which we are all familiar—it is customary, in order to bring out the striking contrasts of color, to bend the tubes into very elaborate designs. The luminosity caused by the phosphorescence of the residual

gas follows all the convolutions into which skillful glass-blowers can manage to twist the glass. The negative pole being at one end and the positive pole at the other, the luminous phenomena seem to depend more on the positive than on the negative at the ordinary exhaustion hitherto used to get the best phenomena of vacuum tubes. But at a very high exhaustion the phenomena noticed in ordinary vacuum tubes when the induction spark passes through them—an appearance of cloudy luminosity and of stratifications—disappear entirely. No cloud

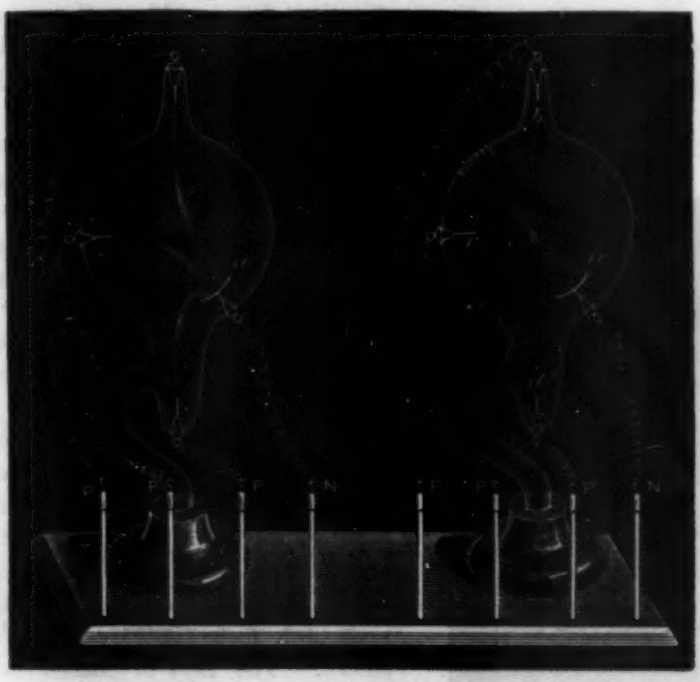
Fig. 6.



or fog whatever is seen in the body of the tube, and with such a vacuum as I am working with in these experiments, the only light observed is that from the phosphorescent surface of the glass. I have here two bulbs (Fig. 7), alike in shape and position of poles, the only difference being that one is at an exhaustion equal to a few millimetres of mercury—such a moderate exhaustion as will give the ordinary luminous phenomena—while the other is exhausted to about the millionth of an atmosphere. I will first connect the moderately exhausted bulb (A) with the induction-coil, and retaining the pole at one side (*a*) always negative, I will put the positive wire successively to the other poles

with which the bulb is furnished. You see that as I change the position of the positive pole, the tinge of violet light joining the two poles changes, the electric current always choosing the shortest path between the two poles, and moving about the bulb as I alter the position of the wires.

Fig. 7.



This, then, is the kind of phenomenon we get in ordinary exhaustions. I will now try the same experiment with a bulb (B) that is very highly exhausted, and as before, will make the side pole (a') the negative, the top pole (b) being positive. Notice how widely diferent is the appearance from that shown by the last bulb. The negative pole is in the form of a shallow cup. The molecular rays from the cup cross in the centre of the bulb, and thence diverging fall on the opposite side and produce a circular patch of green phosphorescent light. As I turn the bulb round you will all be able to see the green patch on the glass. Now observe, I remove the positive wire from the top, and connect it with the side pole (c). The green patch from the divergent negative focus is there still. I now make the lowest pole (d)

positive, and the green patch remains where it was at first, unchanged in position or intensity.

We have here another property of Radiant Matter. In the low vacuum the position of the positive pole is of every importance, while in a high vacuum the position of the positive pole scarcely matters at all; the phenomena seem to depend entirely on the negative pole. If the negative pole points in the direction of the positive, all very well, but if the negative pole is entirely in the opposite direction it is of little consequence; the Radiant Matter darts all the same in a straight line from the negative.

Fig. 8.

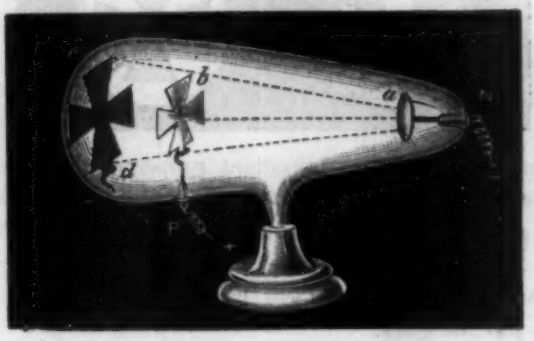
If, instead of a flat disk, a hemi-cylinder is used for the negative pole, the Matter still radiates normal to its surface. The tube before you (Fig. 8) illustrates this property. It contains, as a negative pole, a hemi-cylinder (*a*) of polished aluminium. This is connected with a fine copper wire, *b*, ending at the platinum terminal, *c*. At the upper end of the tube is another terminal, *d*. The induction-coil is connected so that the hemi-cylinder is negative and the upper pole positive, and when exhausted to a sufficient extent the projection of the molecular rays to a focus is very beautifully shown. The rays of Matter being driven from the hemi-cylinder in a direction normal to its surface, come to a focus and then diverge, tracing their path in brilliant green phosphorescence on the surface of the glass.

Instead of receiving the molecular rays on the glass, I will show you another tube in which the focus falls on a phosphorescent screen. See how brilliantly the lines of discharge shine out, and how intensely the focal point is illuminated, lighting up the table.

Radiant Matter when intercepted by Solid Matter casts a Shadow.

Radiant Matter comes from the pole in straight lines, and does not merely permeate all the parts of the tube and fill it with light, as would be the case were the exhaustion less good. Where there is nothing in the way the rays strike the screen and produce phosphorescence, and where solid matter intervenes they are obstructed by it, and a shadow is thrown on the screen. In this pear-shaped bulb (Fig. 9) the negative pole (*a*) is at the pointed end. In the middle is a cross (*b*) cut

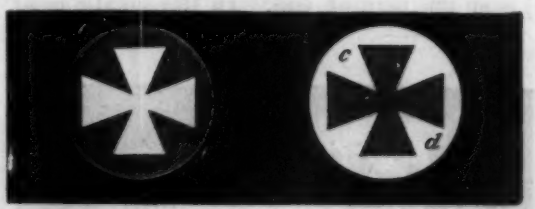
Fig. 9.



out of sheet aluminium, so that the rays from the negative pole projected along the tube will be partly intercepted by the aluminium cross, and will project an image of it on the hemispherical end of the tube, which is phosphorescent. I turn on the coil, and you will all see the black shadow of the cross on the luminous end of the bulb (*c*, *d*). Now, the Radiant Matter from the negative pole has been passing by the side of the aluminium cross to produce the shadow; the glass has been hammered and bombarded till it is appreciably warm, and at the same time another effect has been produced on the glass—its sensibility has been deadened. The glass has got tired, if I may use the expression, by the enforced phosphorescence. A change has been produced by this molecular bombardment which will prevent the glass from responding easily to additional excitement; but the part that the shadow has fallen on is not tired—it has not been phosphorescing at all and is perfectly fresh; therefore if I throw down this cross—I can easily do so by giving the apparatus a slight jerk, for it has been most ingeniously constructed with a hinge by Mr. Gimingham—and so allow the

rays from the negative pole to fall uninterruptedly on to the end of the bulb, you will suddenly see the black cross (*c*, *d*, Fig. 10) change to a luminous one (*e*, *f*), because the background is now only capable of faintly phosphorescing, while the part which had the black shadow on it retains its full phosphorescent power. The stenciled image of the luminous cross unfortunately soon dies out. After a period of rest the glass partly recovers its power of phosphorescing, but it is never so good as it was at first.

Fig. 10.

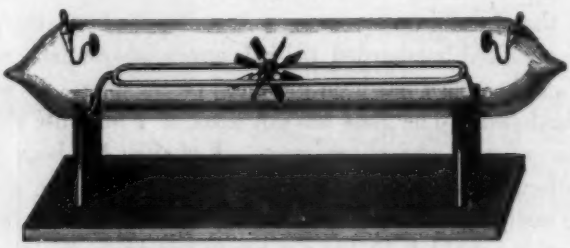


Here, therefore, is another important property of Radiant Matter. It is projected with great velocity from the negative pole, and not only strikes the glass in such a way as to cause it to vibrate and become temporarily luminous while the discharge is going on, but the molecules hammer away with sufficient energy to produce a permanent impression upon the glass.

Radiant Matter exerts Strong Mechanical Action where it strikes.

We have seen, from the sharpness of the molecular shadows, that Radiant Matter is arrested by solid matter placed in its path. If this

Fig. 11.



solid body is easily moved the impact of the molecules will reveal itself in strong mechanical action. Mr. Gimingham has constructed for me an ingenious piece of apparatus which when placed in the elec-

tric lantern will render this mechanical action visible to all present. It consists of a highly exhausted glass tube (Fig. 11), having a little glass railway running along it from one end to the other. The axle of a small wheel revolves on the rails, the spokes of the wheel carrying wide mica paddles. At each end of the tube, and rather above the centre, is an aluminium pole, so that whichever pole is made negative the stream of Radiant Matter darts from it along the tube, and striking the upper vanes of the little paddle-wheel causes it to turn round and travel along the railway. By reversing the poles I can arrest the wheel and send it the reverse way, and if I gently incline the tube the force of impact is observed to be sufficient even to drive the wheel up hill.

Fig. 12.

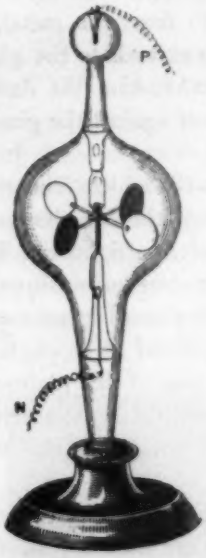
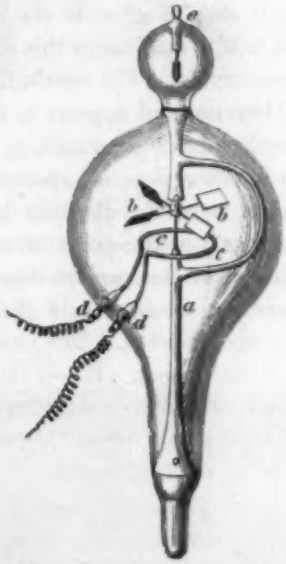


Fig. 13.



This experiment, therefore, shows that the molecular stream from the negative pole is able to move any light object in front of it.

The molecules being driven violently from the pole there should be a recoil of the pole from the molecules, and by arranging an apparatus so as to have the negative pole movable and the body receiving the impact of the Radiant Matter fixed, this recoil can be rendered sensible. In appearance the apparatus (Fig. 12) is not unlike an ordinary radiometer with aluminium disks for vanes, each disk coated on one side with

a film of mica. The fly is supported by a hard steel instead of glass cup, and the needle point on which it works is connected by means of a wire with a platinum terminal sealed into the glass. At the top of the radiometer bulb a second terminal is sealed in. The radiometer, therefore, can be connected with an induction-coil, the movable fly being made the negative pole.

For these mechanical effects the exhaustion need not be so high as when phosphorescence is produced. The best pressure for this electrical radiometer is a little beyond that at which the dark space round the negative pole extends to the sides of the glass bulb. When the pressure is only a few millims. of mercury, on passing the induction current a halo of velvety violet light forms on the metallic side of the vanes, the mica side remaining dark. As the pressure diminishes, a dark space is seen to separate the violet halo from the metal. At a pressure of half a millimetre this dark space extends to the glass, and rotation commences. On continuing the exhaustion the dark space further widens out and appears to flatten itself against the glass, when the rotation becomes very rapid.

Here is another piece of apparatus (Fig. 13) which illustrates the mechanical force of the Radiant Matter from the negative pole. A stem (*a*) carries a needle-point in which revolves a light mica fly (*b b*). The fly consists of four square vanes of thin clear mica, supported on light aluminium arms, and in the centre is a small glass cap which rests on the needle-point. The vanes are inclined at an angle of 45° to the horizontal plane. Below the fly is a ring of fine platinum wire (*c c*), the ends of which pass through the glass at *d d*. An aluminium terminal (*e*) is sealed in at the top of the tube, and the whole is exhausted to a very high point.

By means of the electric lantern I project an image of the vanes on the screen. Wires from the induction-coil are attached, so that the platinum ring is made the negative pole, the aluminium wire (*e*) being positive. Instantly, owing to the projection of Radiant Matter from the platinum ring, the vanes rotate with extreme velocity. Thus far the apparatus has shown nothing more than the previous experiments have prepared us to expect; but observe what now happens. I disconnect the induction-coil altogether, and connect the two ends of the platinum wire with a small galvanic battery; this makes the ring *c c* red hot, and under this influence you see that the vanes spin as fast as they did when the induction-coil was at work.

Here, then, is another most important fact. Radiant Matter in these high vacua is not only excited by the negative pole of an induction-coil, but a hot wire will set it in motion with force sufficient to drive round the sloping vanes.

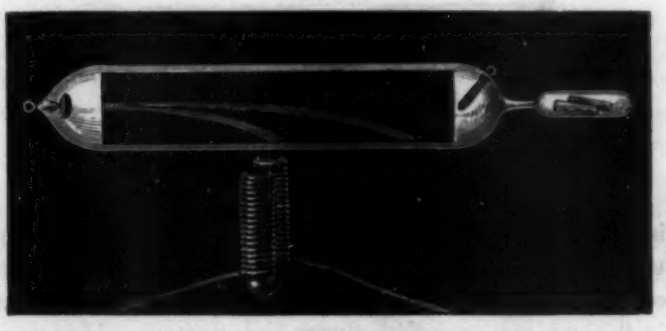
Radiant Matter is deflected by a Magnet.

I now pass to another property of Radiant Matter. This long glass tube (Fig. 14) is very highly exhausted; it has a negative pole at one end and a long phosphorescent screen down the centre of the tube.

Fig. 14.

In front of the negative pole is a plate of mica (*b*, *d*) with a hole (*e*) in it, and the result is, when I turn on the current, a line of phosphorescent light (*e*, *f*) is projected along the whole length of the tube. I now place beneath the tube a powerful horse-shoe magnet; observe how the line of light becomes curved under the magnetic influence waving about like a flexible wand as I move the magnet to and fro.

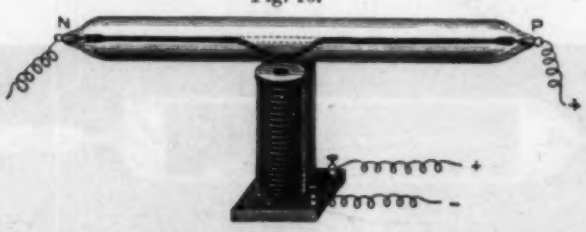
Fig. 15.



This action of the magnet is very curious, and if carefully followed up will elucidate other properties of Radiant Matter. Here (Fig. 15) is an exactly similar tube, but having at one end a small potash tube, which, if heated, will slightly injure the vacuum. I turn on the

induction current, and you see the ray Radiant Matter tracing its trajectory in a curved line along the screen, under the influence of the horseshoe magnet beneath. Observe the shape of the curve. The molecules shot from the negative pole may be likened to a discharge of iron bullets from a mitrailleuse, and the magnet beneath will represent the earth curving the trajectory of the shot by gravitation. Here on this luminous screen you see the curved trajectory of the shot accurately traced. Now suppose the deflecting force to remain constant, the curve traced by the projectile varies with the velocity. If I put more powder in the gun the velocity will be greater and the trajectory flatter, and if I interpose a denser resisting medium between the gun and the target, I diminish the velocity of the shot, and thereby cause it to move in a greater curve and come to the ground sooner. I cannot well increase before you the velocity of my stream of radiant molecules by putting more powder in my battery, but I will try and make them suffer greater resistance in their flight from one end of the tube to the other. I heat the caustic potash with a spirit-lamp and so throw in a trace more gas. Instantly the stream of Radiant Matter responds. Its velocity is impeded, the magnetism has longer time on which to act on the individual molecules, the trajectory gets more and more curved, until, instead of shooting nearly to the end of the tube, my molecular bullets fall to the bottom before they have got more than half way.

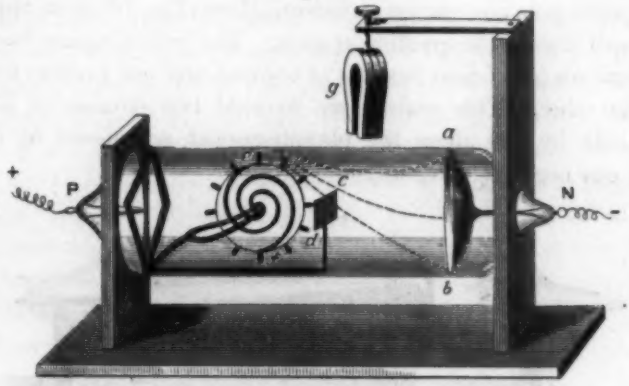
Fig. 16.



It is of great interest to ascertain whether the law governing the magnetic deflection of the trajectory of Radiant Matter is the same as has been found to hold good at a lower vacuum. The experiments I have just shown you were with a very high vacuum. Here is a tube with a low vacuum (Fig. 16). When I turn on the induction spark, it passes as a narrow line of violet light joining the two poles. Underneath I have a powerful electro-magnet. I make contact with the magnet, and the line of light dips in the centre toward the magnet. I reverse the

poles, and the line is driven up to the top of the tube. Notice the difference between the two phenomena. Here the action is temporary. The dip takes place under the magnetic influence; the line of discharge then rises and pursues its path to the positive pole. In the high exhaustion, however, after the stream of Radiant Matter had dipped to the magnet it did not recover itself, but continued its path in the altered direction.

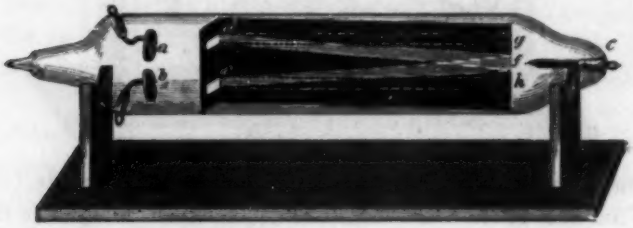
Fig. 17.



By means of this little wheel, skillfully constructed by Mr. Gimingham, I am able to show the magnetic deflection in the electric lantern. The apparatus is shown in this diagram (Fig. 17). The negative pole (a, b) is in the form of a very shallow cup. In front of the cup is a mica screen (c, d), wide enough to intercept the Radiant Matter coming from the negative pole. Behind this screen is a mica wheel (e, f) with a series of vanes, making a sort of paddle-wheel. So arranged, the molecular ray from the pole a b will be cut off from the wheel, and will not produce any movement. I now put a magnet, g, over the tube, so as to deflect the stream over or under the obstacle c d, and the result will be rapid motion in one or the other direction, according to the way the magnet is turned. I throw the image of the apparatus on the screen. The spiral lines painted on the wheel show which way it turns. I arrange the magnet to draw the molecular stream so as to beat against the upper vanes, and the wheel revolves rapidly as if it were an overshot water-wheel. I turn the magnet so as to drive the Radiant Matter underneath; the wheel slackens speed, stops, and then begins to rotate the other way, like an undershot water-wheel. This can be repeated as often as I reverse the position of the magnet.

I have mentioned that the molecules of the Radiant Matter discharged from the negative pole are negatively electrified. It is probable that their velocity is owing to the mutual repulsion between the similarly electrified pole and the molecules. In less high vacua, such as you saw a few minutes ago (Fig. 16), the discharge passes from one pole to another, carrying an electric current, as if it were a flexible wire. Now it is of great interest to ascertain if the stream of Radiant Matter from the negative pole also carries a current. Here (Fig. 18) is an apparatus which will decide the question at once. The tube contains two negative terminals (*a*, *b*) close together at one end, and one positive terminal (*c*) at the other. This enables me to send two streams of Radiant Matter side by side along the phosphorescent screen—or by disconnecting one negative pole, only one stream.

Fig. 18.



If the streams of Radiant Matter carry an electric current they will act like two parallel conducting wires and attract one another; but if they are simply built up of negatively electrified molecules they will repel each other.

I will first connect the upper negative pole (*a*) with the coil, and you see the ray shooting along the line *d*, *f*. I now bring the lower negative pole (*b*) into play, and another line (*e*, *h*) darts along the screen. But notice the way the first line behaves; it jumps up from its first position, *d f*, to *d g*, showing that it is repelled, and if time permitted I could show you that the lower ray is also deflected from its normal direction; therefore the two parallel streams of Radiant Matter exert mutual repulsion, acting not like current carriers, but merely as similarly electrified bodies.

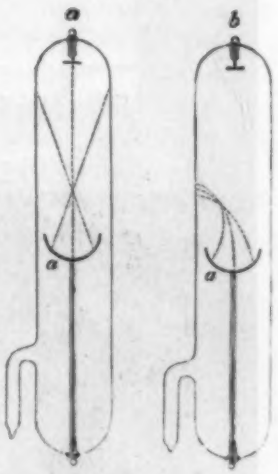
Radiant Matter produces Heat when its motion is Arrested.

During these experiments another property of Radiant Matter has made itself evident, although I have not yet drawn attention to it.

The glass gets very warm where the green phosphorescence is strongest. The molecular focus on the tube, which we saw earlier in the evening (Fig. 8) is intensely hot, and I have prepared an apparatus by which this heat at the focus can be rendered apparent to all present.

I have here a small tube (Fig. 19, *a*) with a cup-shaped negative pole. This cup projects the rays to a focus in the middle of the tube. At the side of the tube is a small electro-magnet, which I can set in action by touching a key, and the focus is then drawn to the side of the glass tube (Fig. 19, *b*). To show the first action of the heat I have coated the tube with wax. I will put the apparatus in front of the electric lantern (Fig. 20, *d*), and throw a magnified image of the tube on the screen. The coil is now at work, and the focus of molecular rays is projected along the tube. I turn the magnetism on, and draw the focus to the side of the glass. The first thing you see is a small circular patch melted in the coating of wax. The glass soon begins to disintegrate, and cracks are shooting starwise from the centre of heat. The glass is softening. Now the atmospheric pressure forces it in, and now it melts. A hole (*e*) is perforated in the middle, the air rushes in, and the experiment is at an end.

Fig. 19.



I can render this focal heat more evident if I allow it to play on a piece of metal; This bulb (Fig. 21) is furnished with a negative pole in the form of a cup (*a*). The rays will therefore be projected to a focus on a piece of iridio-platinum (*b*) supported in the centre of the bulb.

I first turn on the induction-coil slightly, so as not to bring out its full power. The focus is now playing on the metal, raising it to a white heat. I bring a small magnet near, and you see I can deflect the focus of heat just as I did the luminous focus in the other tube. By shifting the magnet I can drive the focus up and down, or draw it completely away from the metal, and leave it non-luminous. I withdraw the magnet, and let the molecules have full play again; the metal

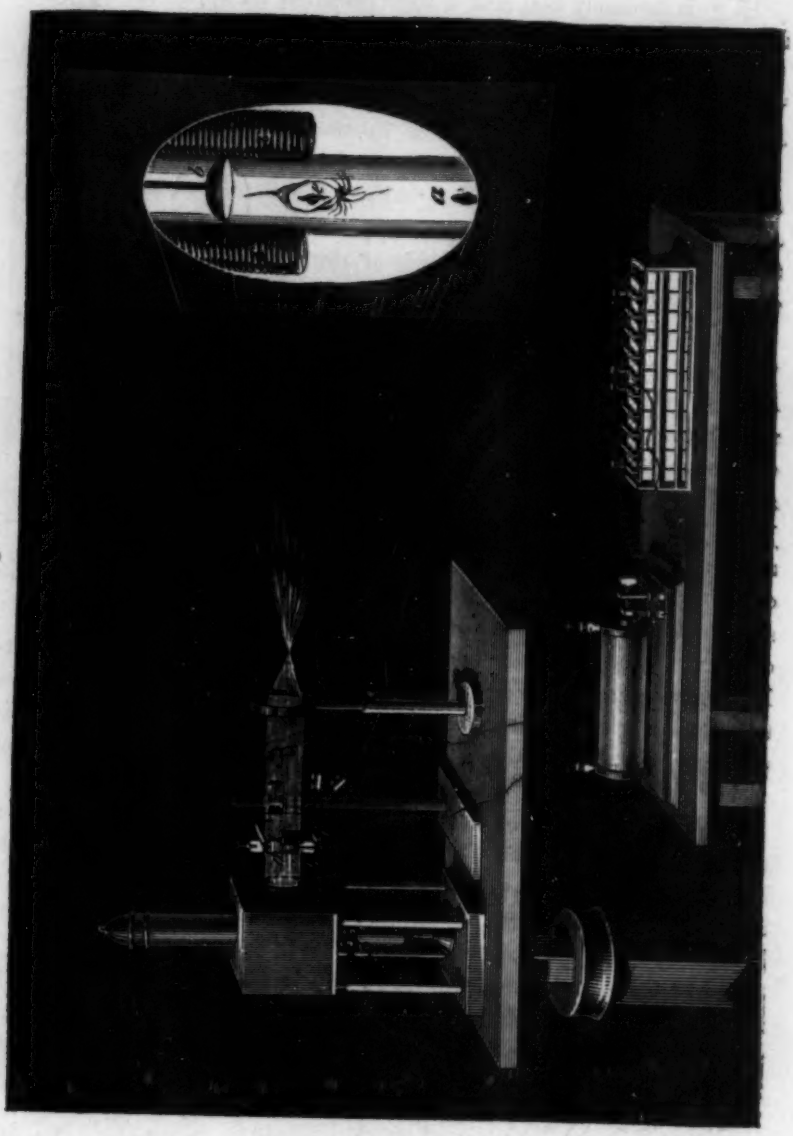


Fig. 20.

is now white hot. I increase the intensity of the spark. The iridio-platinum glows with almost insupportable brilliancy, and at last melts.

The Chemistry of Radiant Matter.

Fig. 21.

As might be expected, the chemical distinctions between one kind of Radiant Matter and another at these high exhaustions are difficult to recognize. The physical properties I have been elucidating seem to be common to all matter at this low density. Whether the gas originally under experiment be hydrogen, carbonic acid, or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, etc., are identical, only they commence at different pressures. Other facts, however, show that at this low density the molecules retain their chemical characteristics. Thus by introducing into the tubes appropriate absorbents of residual gas, I can see that chemical attraction goes on long after the attenuation has reached the best stage for showing the phenomena now under illustration, and I am able by this means to carry the exhaustion to much higher degrees than I can get by mere pumping. Working with aqueous vapor I can use phosphoric anhydride as an absorbent; with carbonic acid, potash; with hydrogen, palladium; and with oxygen, carbon, and then potash. The highest vacuum I have yet succeeded in obtaining has been the 1-20,000,000th of an atmosphere, a degree which may be better understood if I say that it corresponds to about the hundredth of an inch in a barometric column three miles high.

It may be objected that it is hardly consistent to attach primary importance to the presence of *Matter*, when I have taken extraordinary pains to remove as much Matter as possible from these bulbs and these tubes, and have succeeded so far as to leave only about the one millionth of an atmosphere in them. At its ordinary pressure the atmosphere is not very dense, and its recognition as a constituent of the

world of Matter is quite a modern notion. It would seem that when divided by a million, so little Matter will necessarily be left that we may justifiably neglect the trifling residue and apply the term *vacuum* to space from which the air has been so nearly removed. To do so, however, would be a great error, attributable to our limited faculties being unable to grasp high numbers. It is generally taken for granted that when a number is divided by a million the quotient must necessarily be small, whereas it may happen that the original number is so large that its division by a million seems to make little impression on it. According to the best authorities, a bulb of the size of the one before you (13·5 centimetres in diameter) contains more than 1,000000,000000,000000,000000 (a quadrillion) molecules. Now, when exhausted to a millionth of an atmosphere we shall still have a trillion molecules left in the bulb—a number quite sufficient to justify me in speaking of the residue as *Matter*.

To suggest some idea of this vast number I take the exhausted bulb, and perforate it by a spark from the induction coil. The spark produces a hole of microscopical fineness, yet sufficient to allow molecules to penetrate and to destroy the vacuum. The inrush of air impinges against the vanes and sets them rotating after the manner of a windmill. Let us suppose the molecules to be of such a size that at every second of time a hundred millions could enter. How long, think you, would it take for this small vessel to get full of air? An hour? A day? A year? A century? Nay, almost an eternity! A time so enormous that imagination itself cannot grasp the reality. Supposing this exhausted glass bulb, indued with indestructibility, had been pierced at the birth of the solar system; supposing it to have been present when the earth was without form and void; supposing it to have borne witness to all the stupendous changes evolved during the full cycles of geologic time, to have seen the first living creature appear, and the last man disappear; supposing it to survive until the fulfillment of the mathematicians' prediction that the sun, the source of energy, four million centuries from its formation will ultimately become a burnt-out cinder;* supposing all this—at the rate of filling I have just described, 100 million molecules a second—this little bulb

* The possible duration of the sun from formation to extinction has been variously estimated, by different authorities, at from 18 million years to 400 million years. For the purpose of this illustration I have taken the highest estimate.

even then would scarcely have admitted its full quadrillion of molecules.*

But what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopic hole before you leave this room? The hole being unaltered in size, the number of molecules undiminished, this apparent paradox can only be explained by again supposing the size of the molecules to be diminished almost infinitely—so that instead of entering at the rate of 100 millions every second, they troop in at the rate of something like 300 trillions a second. I have done the sum, but figures when they mount so high cease to have any meaning, and such calculations are as futile as trying to count the drops in the ocean.

In studying this Fourth state of Matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties Radiant Matter is as material as this table, whilst in other properties it almost assumes the character of Radiant Energy. We have actually touched the border land where Matter and Force seem to merge into one another, the shadowy realm between Known and Unknown, which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this Border Land, and even beyond; here, it seems to me, lie Ultimate Realities, subtle, far-reaching, wonderful.

"Yet all these were, when no Man did them know,
Yet have from wisest Ages hidden beene;
And later Times thinges more unknowne shall show.
Why then should witlesse Man so much misweene,
That nothing is, but that which he hath seene?"

* According to Mr. Johnstone Stoney (Phil. Mag., vol. xxxvi, p. 141), 1 c.c. of air contains about 1000,000000,000000,000000 molecules. Therefore a bulb 13·5 centimetres diameter contains $13{\cdot}5^3 \times 0{\cdot}5236 \times 1000,000000,000000,000000$, or 1,288252,350000,000000,000000, molecules of air at the ordinary pressure. Therefore the bulb, when exhausted to the millionth of an atmosphere, contains 1,288252,350000,000000 molecules, leaving 1,288251,061747,650000,000000 molecules to enter through the perforation. At the rate of 100,000000 molecules a second, the time required for them all to enter will be

12882,510617,476500 seconds, or
214,708510,291275 minutes, or
3,578475,171521 hours, or
149103,132147 days, or
408,501731 years.

A NEW ILLUSTRATION OF "PERSISTENCE OF VISION."

By THOMAS WILLIAM TOBIN,
Professor of Chemistry and Physics, Central University, Richmond, Ky.

The accompanying optical illusion, described and exhibited by Professor S. P. Thompson, of University College, Bristol, England, has been noticed by many of the European and American scientific journals, as a great curiosity. "If the illustration" (Fig. 1), says the inventor, "is moved by the hand in a small circle without rotating it, or if it is given the same motion that is required to rinse out a pail, the circles will revolve around their centres in the same direction that the drawing moves, and will complete a revolution as the drawing completes its circular motion. The central figure will also revolve, but in the contrary direction.

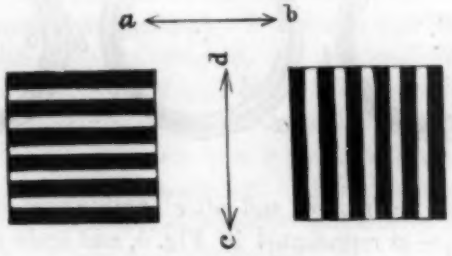
Fig. 1.

"No satisfactory explanation of these phenomena has as yet been given. It is suggested that the key to the mystery may perhaps be found in the property of the eye which Brewster and others call 'compensation'; that is, the tendency of a repeated or continuous movement to cause a sensation complementary to the real one. For instance, if we gaze at the rocks in a cascade and then at the cascade

alternately, for a short time, the rocks will appear to move upward; or if we examine a stream below a waterfall, the water will appear to flow much faster in the middle than at the sides of the stream. If we look at the middle and sides alternately, the water will seem to flow backward."

This does not afford a satisfactory explanation of the phenomenon. The principle involved is undoubtedly that of "Persistence of Vision," or that property of the retina of the eye, of retaining any image impressed upon it for a perceptible interval of time. This interval of persistence "varies with the sensitiveness of the retina and the intensity of light" (Ganot), and has been found by Pleteau to average half a second.

Fig. 2. Fig. 3.



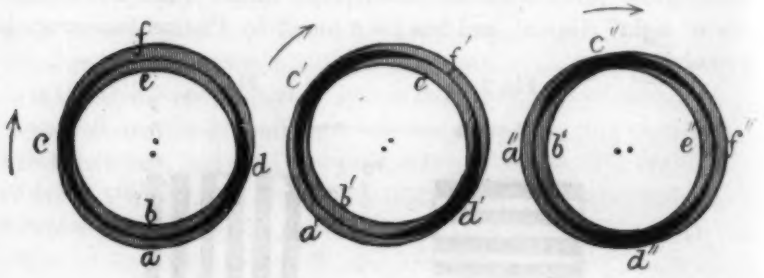
Draw a number of thick black lines and equal white spaces intervening, horizontally and vertically, as in Figs. 2 and 3. If now these figures be moved quickly in the directions of the double arrow, *ab*, it is evident that, providing each black line in Fig. 3 replaces the adjacent white line in less than half a second, both images of black and white lines will be superimposed upon the retina, and the effect produced of a grey, indistinct appearance. The same motion will not produce this effect on Fig. 2, as there the similar lines will always superimpose, and the eye will retain the intensities of both black and white lines. Moving the figures in the same manner, but in the directions *cd*, these effects will be reversed, *i. e.*, Fig. 2 will be indistinct, and Fig. 3 bright and intense.

Now, applying these conditions to curved lines and circles, we have the same results; but, as there are no two continuous points in a curve or circle, the intense portions of the lines will be governed by the motion of the figure, and in a circle moved in a circular direction. The

intense portions will partake of the circular motion, as may be explained by the following figures:

Assume that one of the black circles of Fig. 1, and represented by a, c, e, d, Fig. 4, is moved in a circular direction, as indicated by the arrow, if in half a second or less it arrived at the position b, c, f, d, there will be two intense or superimposed portions, c and d, the remainder of the figure being grey, or indistinct.

Fig. 4. Fig. 5. Fig. 6.



Let us follow the motion, and after another part of the revolution the circle will be as represented in Fig. 5, and again in half a second from that position the intense portions will be at c' and d'. At a third interval we will find the intense portions, as in Fig. 6, at c'' and d'', and so on, but continuous throughout an entire circle.

It is the movement of these intense spots over the grey, or indistinct circles that lends the illusion of revolution. In the strict sense of the meaning, the circles cannot appear to revolve, because revolution of a perfect and uniform circle is imperceptible to the eye. It is essential that some prominent part or parts indicate the motion. The parts c and d are made prominent by their intensity, and revolve as shown. The same line of reasoning applies equally to the white as well as the black circles, in regard to their intensities.

This seems to be the rational explanation of the phenomena, which may be verified in a number of consequent experiments, too numerous to describe here.

Artificial Indigo.—Prof. Baeyer, of Munich, has discovered a systematic method for the artificial preparation of this valuable dye.—*Ind. Blätter.* C.

THE ACTION OF HEAT IN VACUO ON METALS.*

By T. A. Edison.

In the course of my experiments on electric lighting I have developed some striking phenomena arising from the heating of metals by flames and by the electric current, especially wires of platinum, and platinum alloyed with iridium. These experiments are in progress.

The first fact observed was that platinum lost weight when heated in a flame of hydrogen, that the metal colored the flame green, and that these two results continued until the whole of the platinum in contact with the flame had disappeared. A platinum wire four-thousandths of an inch in diameter, and weighing 306 m.grms., was bunched together and suspended in a hydrogen flame. It lost weight at the rate of a fraction less than 1 m.grm. per hour as long as it was suspended in the flame. When a platinum wire is stretched between two clamping posts, and arranged to pass through a hydrogen flame, it is colored a light green; but when the temperature of the wire is raised above that of the flame, by passing a current through it, the flame is colored a deep green. To ascertain the diminution in the weight of a platinum wire when heated by the electric current, I placed between two clamping posts a wire five-thousandths of an inch in diameter, and weighing 266 m.grms. This wire, after it was brought to incandescence for twenty minutes by the current, lost 1 m.grm. The same wire was then raised to incandescence; for twenty minutes it gave a loss of 3 m.grms. Afterward it was kept incandescent for one hour and ten minutes, at which time it weighed 258 m.grms., a total loss of 8 m.grms. Another wire, weighing 343 m.grms., was kept moderately incandescent for nine consecutive hours, after which it weighed 301 m.grms., showing a total loss of 42 m.grms. A platinum wire twenty-thousandths of an inch in diameter was wound in the form of a spiral one-eighth of an inch in diameter and one-half an inch in length. The two ends of the spiral were secured to clamping posts, and the whole apparatus was covered with a glass shade 2½ inches in diameter and 3 inches high. Upon bringing the spiral to incandescence for twenty minutes that part

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of the globe in line with the sides of the spiral became slightly darkened; in five hours the deposit became so thick that the incandescent spiral could not be seen through the deposit. This film, which was most perfect, consisted of platinum, and I have no doubt but that large plates of glass might be coated economically by placing them on each side of a large sheet of platinum, kept incandescent by the electric current. This loss in weight, together with the deposit upon the glass, presented a very serious obstacle to the use of metallic wires for giving light by incandescence, but this was easily surmounted after the cause was ascertained. I coated the wire forming the spiral with the oxide of magnesium by dusting upon it finely powdered acetate of magnesium: while incandescent the salt was decomposed by the heat, and there remained a strongly adherent coating of the oxide. This spiral so coated was covered with a glass shade, and brought to incandescence for several minutes; but, instead of a deposit of platinum upon the glass, there was a deposit of the oxide of magnesia. From this and other experiments I became convinced that this effect was due to the washing action of the air upon the spiral; that the loss of weight in and the coloration of the hydrogen flame were also due to the wearing away of the surface of the platina to the attrition produced by the impact of the stream of gases upon the highly incandescent surface, and not to volatilization, as commonly understood; and I venture to say, although I have not tried the experiment, that metallic sodium cannot be volatilized in high vacua by the heat derived from incandescent platinum; any effect that may be produced will be due to the washing action of the residual air. After the experiment last described I placed a spiral of platinum in the receiver of a common air-pump, and arranged it in such a manner that the current could pass through it, while the receiver was exhausted. At a pressure of 2 millimetres the spiral was kept at incandescence for two hours before the deposit was sufficient to become visible. In another experiment, at a higher exhaustion, it required five hours before a deposit became visible. In a sealed glass bulb, exhausted by a Sprengel pump to a point where a quarter of an inch spark from an induction-coil would not pass between points 1 millimetre apart, was placed a spiral, the connecting wires passing through the glass. This spiral has been kept at the most dazzling incandescence for hours without the slightest deposit becoming visible.

I will now describe other and far more important phenomena

observed in my experiments. If a short length of platinum wire one-thousandth of an inch in diameter be held in the flame of a Bunsen burner, at some part it will fuse, and a piece of the wire will be bent at an angle by the action of the globule of melted platinum; in some cases there are several globles formed simultaneously, and the wire assumes a zigzag shape. With a wire four-thousandths of an inch in diameter this effect does not take place, as the temperature cannot be raised to equal that of the smaller wire, owing to the increased radiating surface and mass. After heating, if the wire be examined under a microscope, that part of the surface which has been incandescent will be found covered with innumerable cracks. If the wire be placed between clamping posts, and heated to incandescence for twenty minutes, by the passage of an electric current, the cracks will be so enlarged as to be seen with the naked eye; the wire, under the microscope, presents a shrunken appearance, and is full of deep cracks. If the current is continued for several hours these effects will so increase that the wire will fall to pieces. This disintegration has been noticed in platina long subjected to the action of a flame by Prof. John W. Draper. The failure of the process of lighting invented by the French chemist Tessie du Motay, who raised sheets of platinum to incandescence by introducing them into a hydrogen flame, was due to the rapid disintegration of the metal. I have ascertained the cause of this phenomenon, and have succeeded in eliminating that which produces it, and in doing so have produced a metal in a state hitherto unknown, and which is absolutely stable at a temperature where nearly all substances melt or are consumed; a metal which, although originally soft and pliable, becomes as homogeneous as glass and as rigid as steel. When wound in the form of a spiral it is as springy and elastic when at the most dazzling incandescence as when cold, and cannot be annealed by any process now commonly known, for the cause of this shrinking and cracking of the wire is due entirely to the expansion of the air in the mechanical and physical pores of the platinum, and the contraction upon the escape of the air. Platinum as sold in commerce may be compared to sandstone, in which the whole is made of a great number of particles with many air spaces. The sandstone upon melting becomes homogeneous and no air spaces exist.

With platinum or any metal the air spaces may be eliminated, and the metal made homogenous by a very simple process. This process I will now describe. I had made a large number of platinum spirals,

all of the same size and from the same quality of wire; each spiral presented to the air a radiating surface of three-sixteenths of an inch; five of these were brought by the electric current up to the melting-point, the light was measured by a photometer, and the average light was equal to four standard candles for each spiral just at the melting point. One of the same kind of spirals was placed in the receiver of an air-pump, and the air exhausted to 2 millimetres; a weak current was then passed through the wire, to slightly warm it for the purpose of assisting the passage of the air from the pores of the metal into the vacuum. The temperature of the wire was gradually augmented, at intervals of ten minutes, until it became red. The object of slowly increasing the temperature was to allow the air to pass out gradually and not explosively. Afterward the current was increased at intervals of fifteen minutes. Before each increase in the current the wire was allowed to cool, and the contraction and expansion at these high temperatures caused the wire to weld together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of twenty-five standard candles, whereas it would undoubtedly have melted before it gave a light of five candles had it not been put through the above process. Several more spirals were afterwards tried, with the same result. One spiral, which had been brought to these high temperatures more slowly, gave a light equal to thirty standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature. Upon examination of these spirals, which had passed through the vacuum process, by the aid of a microscope no cracks were visible; the wire had become as white as silver, and had a polish which could not be given it by any other means. The wire had a less diameter than before treatment, and it was exceedingly difficult to melt in the oxy-hydrogen flame. As compared with untreated platinum, it was found that it was as hard as the steel wire used in pianos, and that it could not be annealed at any temperature.

My experiments with many metals treated by this process have proved to my satisfaction, and I have no hesitation in stating that what is known as annealing of metals to make them soft and pliable is nothing more than the cracking of the metal. In every case where a hard drawn wire had been annealed a powerful microscope revealed myriads of cracks in the metal. Since the experiments of which I have just

spoken I have, by the aid of Sprengel mercury pumps, produced higher exhaustion, and have, by consuming five hours in excluding the air from the wire and intermitting the current a great number of times, succeeded in obtaining a light of eight standard candles from a spiral of wire with a total radiating surface of 1-32d of an inch, or a surface about equal to one grain of buckwheat. With spirals of this small size which have not passed through the process, the average amount of light given out before melting is less than one standard candle. Thus I am enabled, by the increased capacity of platinum, to withstand high temperatures to employ small radiating surfaces, and thus reduce the energy required for candle light. I can now obtain eight separate jets, each giving out an absolutely steady light, and each equal to sixteen standard candles, or a total of 128 candles, by the expenditure of 30,000 foot-pounds of energy, or less than one-horse power. As a matter of curiosity I have made spirals of other metals, and excluded the air from them in the manner stated. Common iron wire may be made to give a light greater than platinum not heated. The iron becomes as hard as steel, and just as elastic. Nickel is far more refractory than iron. Steel wire used in pianos becomes decarbonized, but remains hard, and becomes the color of silver. Aluminum melts only at a white heat.

In conclusion, it may be interesting to state that the melting-points of many oxides is dependent on the manner of applying the heat; for instance, pure oxide of zirconium does not fuse in the flame of the oxy-hydrogen blow-pipe, while it melts like wax and conducts electricity when on an incandescent platinum spiral which is at a far lower temperature; on the other hand, oxide of aluminum easily melts in the oxy-hydrogen flame, while it only vitrifies on the platinum-spiral.

Climatic Influence of Forests.—The meteorological observations of Messrs. Fautrat and Mathieu show that the influence of coniferous trees upon the distribution of rain is twice as great as that of the angiosperms. Pine forests are especially serviceable in the protection of springs and in the prevention of heavy showers and water-spouts. The circulation of air, on account of the differences of temperature above and under the trees, the condensation of vapor, and the cooling influences upon the atmosphere, tend to produce a uniformity of climate similar to that of the sea shore.—*Baeyer. Ind. u. Gewerbeblätter.* C.

THE FORMATION OF COAL.

The paper read by M. Frémy, the eminent Director of the Museum at the Parisian Académie des Sciences, under the title "Chemical Researches respecting the Formation of Coal," is of such great interest that we have no hesitation in making it known to our readers.

It is known that coal is produced by the decomposition of vegetable matter, which for many ages covered the surface of the earth. The learned chemist has made a series of analyses, of which he gives an account in his paper, and which have enabled him to establish the laws of this decomposition, and to explain the transformation of the tissues of the vegetable matter into coal by the loss of their organic form.

With reference to peat, the hypothesis has been put forth generally up to the present time of a possible relation between their formation and that of coal. M. Frémy has been led by the same investigations to the conclusion that the peaty fermentation is, so to speak, the first stage reached by the ligneous tissues before arriving at their complete transformation into coal.

After making these short preliminary remarks, we hasten to introduce M. Frémy in his own words.

The paper, says M. Frémy, which I read to-day on the formation of coal is the latter part of the general investigations on the vegetable tissues which I have carried on since 1850, that is to say, since my nomination to the professorship of the museum.

It is at the Jardin des Plantes that I have found everything needful for pursuing my enquiries into certain matters highly interesting and important to chemistry and vegetable physiology.

The questions which I proposed to myself were as follows:

What is the nature of the elements of which the organs and the tissues of vegetables are formed? Is it possible to discover these elements without altering them, and to determine with some exactness their proportions? Does this chemical analysis of the tissues permit of following the development in the vegetable organization, and of establishing a comparison between them such as science demands? Is it possible for chemistry to make known the exact composition of these elements, at present but imperfectly defined, such as chloro-

phyllus gum, the gelatinous substances of fruits, which are found in a great number of tissues, and which certainly play an important part in the vegetable organization? Lastly, will it be possible, when all these substances are understood, to determine under what influences the tissues of these vegetables are capable of being transformed into fossil fuel, such as lignite, coal and anthracite?

Taking this programme as the basis of my researches, I shall make a rapid survey of those investigations by which I sought to establish the nature and composition of those substances forming the skeleton or framework of vegetable matter.

The organic elements which I first examined were but little known. Their characteristic property is to produce, under the influence of fermentation or by the action of chemical reagents, a series of gummy and gelatinous substances. They may be confounded with the cell-walls themselves when they are merely subjected to microscopical examination. They often join the cells together, as is shown in the tissue forming the pith of the elder tree. I have demonstrated that the gelatinous substances of vegetables are derived from a primal insoluble substance which I have named *pectose*, and which, by successive polymerical transformations, forms at first gummy substances, then gelatinous bodies, and lastly a soluble acid, the strength of which may be compared with that of the acids found in fruits. All these transformations are produced during the growth of the vegetation.

M. Frémy then undertook the investigation of the properties and nature of the stable and fixed bodies forming the fibres, the cells and the ducts. From these researches it results that the vegetable framework is not so simple as was commonly supposed. It is not constituted of a single substance, the cellular variously incrusted with foreign substances, but of several kinds of isomeric cellular substances. In addition to this, a very important body is also met with, which differs from the cellular in respect to its composition and properties, a body which runs abundantly in the ducts, and which M. Frémy has for this reason called *vasculose*. It is this substance which causes the hardness and density of the ligneous tissues to vary according to the proportion in which it is contained. Oak may contain 30 per cent. of it, and as much as 50 per cent. may be found in nutshells. The *vasculose* is placed between the walls of the fibres and the cells, and unites them. It is dissolved by caustic alkalies.

After these internal tissues M. Frémy studied the bodies which

cover and protect them, such as the cuticle. He called by the name of *cutose* the substance which forms the cuticle, and which is even found in cork. It is rsmarkable for its fixity, and is scarcely affected by sulphuric acid. Lastly, to complete this general study, the learned Director of the Museum examined those bodies which are most frequently met with in the tissues. Gum, for instance, is not a neutral substance, as has been commonly supposed, but a veritable salt, resulting from the combination of a genuine acid with lime. The chlorophyllus itself is not a neutral substance. It is formed of a bluish-green alkaline salt, phyllocyanate of potassa.

These preliminary researches being concluded, M. Frémy placed the top stone to the edifice by attempting the solution of the difficult and interesting problem of the formation of fossil fuel. If vegetable palæontology has made such great progress in these latter times, it may be said that the chemical part of the question has remained in absolute darkness. We know not under what influences the vegetable organization has been destroyed to form this black bituminous mass, partly fusible, non-organic, and insoluble in dissolvents, which constitutes coal. This substance neither resembles the pyrogenous bodies produced in our laboratories nor the ligneous tissues which have formed it. By distillation it gives forth volatile products which do not resemble those given by wood. It leaves also, as a fixed body, a special substance called coke, which is very different from charcoal.

Having already introduced this question in a previous paper, M. Frémy mentioned several chemical reactions which characterized wood, peat, lignite, coal and anthracite. Wood is not perceptibly affected by a diluted solution of potassa, whereas peat often renders to this alkali considerable quantities of ulmic acid. Xyloide lignite, or fossil wood, also coutains notable proportions of ulmic acid; but it is not to be confounded either with wood or with peat, because it is transformed into yellow resin by nitric acid, and is completely soluble in hypochlorites. Compact or perfect lignite does not contain any sensible quantity of ulmic acid, but is soluble in nitric acid and hypochlorites. With respect to coal and anthracite, they are characterized by their insolubility in all the neutral solvents, acids, alkalies and hypochlorites.

The experiments of M. Daubrée upon anthracite, and the no less interesting experiments of M. Baroullier upon coal, lead us to think that the transformation into coal is brought about by the action of

heat and pressure upon the vegetable matters. In order to analyze the phenomenon, M. Frémy arranged a series of tests, in which the vegetable tissues, on the one hand, and, on the other, those substances which most frequently accompany them in the organization, were heated to between 200° and 300° for some hours in glass tubes sealed at both ends.

In these experiments M. Frémy observed a great modification. The tissues became black, brittle, and free from water, acids, gas and tar; but they retained their original organization, and furnished a fixed product, offering no resemblance to coal.

The learned academician then submitted to the same test a certain number of bodies produced by organism, such as sugar, starch, gum, etc., and arrived at very different results. These bodies were transformed into substances having a certain analogy to coal: they were black, shiny, often melted, and quite insoluble in acids and alkalies.

The analysis of these bodies, which M. Frémy designates by the name of coally substances, has demonstrated the complete analogy of their composition with that of natural coal. Coal from gum gives in analysis almost the same quantities of carbon, hydrogen and oxygen as natural coal.

From these coincidences of composition M. Frémy draws the conclusion that the elements contained in the vegetable cells—such as sugar, starch, and gum—play an important part in the production of coal.

This result was doubtless a very interesting one; but, in order to complete it, it was necessary to explain how the tissues of vegetables could lose their organic form and produce the amorphous mass called coal. Besides this, also, it was necessary that the tissues should be proved to be capable of undergoing the same coal transformation which was realized by operating upon the non-organic bodies which accompanied them.

The studies of the eminent chemist with respect to lignite and peat now proved of great assistance to him. He had seen in these combustibles the ulmic acid appear in proportion as the ligneous tissues lost their organization. When a peat was advnced he only found insignificant remains of organic tissue, but then it dontained from 50 to 60 per cent. of ulmic acid. On examining the fossil wood M. Frémy found pretty thick, black, and shining layers of ulmic acid

proceeding from the transformation of *vasculose* besides the ligneous fibres, which were not yet completely disorganized.

This observation demonstrated the transformation on the spot, and in the ligneous tissue itself, of a part of the wood into ulmic acid. In this way M. Frémy was led to admit the fact which appeared to predominate in his researches, that the vegetable matter was first changed into peat before producing coal, and that in this modification the disappearance of the organic tissues was owing to a kind of peaty fermentation. To confirm this hypothesis he found it necessary to prove that the ulmic acid could, like the bodies previously experimented upon, be transformed into coal.

In consequence M. Frémy studied the transformation of three kinds of ulmic acid, and discovered that, after a calcination of 120 hours, the ulmic acid of the peat was converted into artificial coal, presenting the same composition as the coal of Blanzy.

Lastly, the mixtures of chlorophyllus, fatty bodies and resins obtained from leaves by treating them with alcohol, when submitted to the same operation,—that is to say, heated under the pressure of 150 hours,—produced a black, viscous, odorous substance, insoluble in alkalies, and presenting an evident analogy with natural bitumen.

From these facts M. Frémy draws the following conclusions:

1. Coal is a substance which proceeds from the transformation of vegetable matter, but which no longer preserves its organic form.

2. The vegetable marks which the coal presents are produced by it, as in schist or other mineral substances, and do not prove its organization. This fuel is a bituminous and plastic matter, on which the external features of the vegetation are moulded. When a piece of coal presents on its surface, or within its interior, marks of vegetation, it is not to be thence inferred that the adjacent parts are necessarily the result of the alteration of the tissues which were covered by the membranes whose form has been preserved.

3. The principal bodies contained in the vegetable cells, submitted to the double influence of heat and pressure, produce substances which present the properties and composition of coal.

4. The coloring, resinous and fatty matters contained in the leaves are changed, by the action of heat and pressure, into substances which approach very nearly to natural bitumen.

5. With regard to the ligneous tissues at the base of the *cellulose* and the *vasculose*, they are not transformed directly into coal. Before

being so changed they pass through a process of peaty fermentation, which produces ulmic acid. It is only in the second place that this ulmic acid is transformed into coal, mingling with all the coal-forming substances produced by the contents of the cells.—*L'Houille.*

REGENERATIVE SYSTEM FOR GAS-LIGHT.

Mr. F. Siemens, of Dresden, Germany, like his brother, a prominent electrician and inventor, has published in the *Verhandl. z. Bef. d. Gewerb.* a valuable application of his regenerative system for gas-light. Starting from the fact that the intensity of the light is increased by an increase in the temperature of combustion, he designed a number of different styles of lamps in which the air for the combustion of gas is heated by the waste gases, the supply of air being regulated by the currents produced by the difference of the temperature of the air, the gas and the products of combustion. The lamp consists of three iron tubes of suitable diameters, placed one within the other, the upper portion of the lamp being enclosed in a spherical globe. The entire space inclosed by the different tubes is filled with wire netting, constituting what Mr. Siemens calls regenerators, and which serve for absorbing the heat of the products of combustion and for giving it off to the gas and the air for burning the latter. The central tube is used for conveying the gas, which enters it from below. The air is admitted from below into the annular space between the central and second tube, while the hot products of combustion descend through the annular space between the second and the third tube. By this means the heat absorbed by the wire netting in the outer tube will be conducted and reflected to the two inner ones, and serve to heat air and gas and increase the intensity of the flame. The products of combustion rise upward within the space inclosed by the gas globe, and then descend along its sides, until they reach the annular space of the regenerator, without impeding the flow of air or gas. Mr. Siemens has constructed the lamp in such a manner that the regenerator, having a disc shape, serves as a reflector at the same time. While the construction of these lamps is not such as to make the system readily applicable to single burner lights, it is destined to enlarge or maintain within certain limits the ground which gas has been rapidly losing in its competition with the electric light for the illumination of large spaces.—*Iron Age.*

PATENT METAL JACKET AND MOVABLE BOILER AND PIPE COVERING.

By I. NEWTON PEIRCE.

Read before the Franklin Institute at its meeting, Sept. 17th, 1879.

As early as 1799 among the methods of saving heat and protecting steam from condensation air was tried as a non-conductor. Ever since then "dead," or confined air, has been considered the best non-conducting medium with which to surround steam boilers, steam pipes and hot-blast pipes. The great expense attending the usual methods for accomplishing this, as well as the imperfect manner in which it has been done, has been a serious objection to its general adoption. By this invention the material used is so cheap, the method so simple, its application so easy and the covering so strong and durable that it comes at once within the reach of all using boilers and pipes. In most instances where boilers and their connecting steam pipes are covered by this method the saving in fuel, in five or six months, pays for the entire expense of this covering.

The material used by this method—to make a "dead air space" around the boiler or pipe—is common sheet-iron No. 28. After being cut into desired sizes it is punched all over its surface into small holes, somewhat in the shape of a V, leaving the top of the V attached to the sheet, and then bending it so as to be at right angles with the sheet, at the same time giving this V point a concave or spoon shape, that it may have the greatest possible strength. These pieces of punched sheet-iron are then bent or shaped to fit the boiler or pipe they are intended to cover, sometimes having break-joints in them by which they can be attached to each other. If for a steam pipe, these pieces are about half the circumference of the pipe, with a break-joint on one edge of each, to fit into each other at the top or on one side of the pipe, with the bottom or opposite side overlapping each other. The points of the V's resting against the boiler or pipe keep the surface of the sheet-iron equi-distant in every part from the surface of the boiler or pipe, thus producing and preserving an equal air-space surrounding the boiler or pipe. It then remains to confine this air and prevent any circulation. This is done by covering this metal

jacket with some good non-conducting plastic, or hair, or asbestos, or paper felting. The holes in the sheet-iron afford the best opportunity for any plastic felting to clinch and fasten itself firmly to the metal jacket.

To make this covering a movable one it is only necessary to turn up the edges of the metal jacket about an inch, at right angles to the general surface, in the form of flanges. When placed on the boiler or pipe the flanges are brought closely together and are fastened there by U-shaped pieces of wire slipped over the two flanges, and the plastic or other felting is put on in the usual manner; the flanges protecting the edges from being injured when the covering is handled by being removed and putting on again.

To remove any section of this covering it is only necessary to pull out the wire U's or clamps that are on the flanges of this section, and lift the section off. All the other sections will remain firmly attached, and when put back again and the clamps put in their places the section becomes as firm as at first.

For the purpose of making repairs to boilers, or allowing them to be inspected, this movable feature becomes a very great convenience.

Temperature of the Sun.—Newton, Waterston, Ericsson and Senchi have asserted that the sun's temperature cannot be less than from one to two millions of degrees (1,800,000 to 3,600,000°F.); Pouillet, Vicaire, Violle and many others maintain that the temperature cannot exceed from 1500° to 2500° (2700° to 4500°F.). The French Academy, in 1876, offered a *Bordin Prize* for the solution of the question, which resulted in a reward to Violle, certificates of "honorable mention" to Vicaire and Crova, and a withdrawal of the prize, in consequence of the difficulty and uncertainty involved in the question. Senchi obtained more than 2,000,000° by Newton's formula, while Violle obtained only 1500° by the formula of Dulong and Petit from the same set of observations. F. Rosetti, in a memoir crowned by the Royal *Academia dei Lincei* discusses experiments and methods of his own, from which he concludes that the temperature cannot be much less than 10,000° (18,000°F.) or much more than 20,000° (36,000°F.).—*Ann. de Chim. et de Phys.* C.

STUDIES ON ULTRAMARINE.

The composition of natural ultramarine is by no means constant. The carbonate of lime found in it by Gmelin to the extent of 28 per cent. belongs to the gangue in which the lazulite is imbedded. Natural ultramarine does not resist alum and acids, but is decomposed by them with liberation of hydrogen sulphide often more readily than are artificial samples. There is consequently no means of distinguishing the natural from the facticious product. Dilute acids decompose artificial ultramarine with the evolution of sulphuretted hydrogen and sulphurous acid. The rose-colored kinds give off sulphurous acid alone. Concentrated sulphuric acid is without action. Hot concentrated solutions of caustic alkalies turn the color from blue to grey. Saturated solutions of alum decompose ultramarine slowly in the cold, but more rapidly with the aid of heat. At about 200° it is converted by acids into a violet ultramarine, which finally becomes red. Ultramarine may be heated to redness without being decolorized, and with certain precautions it may even be incorporated in melted glass, but it begins to be affected at 120° and becomes less brilliant. The complete analysis of ultramarine is very laborious. The author gives here a process sufficient for the requirements of the manufacturer, and showing the silica, alumina, total sulphur and soda. The sample is first decomposed by fuming nitric acid. No sulphuretted hydrogen escapes, and the total sulphur remains in the liquid as sulphuric acid. The liquid is evaporated to dryness, the residue is taken up in a little water acidulated with hydrochloric acid, evaporated a second time, again dissolved in acidulated water, and the silica remaining undissolved is washed with cold water upon the filter. In the filtrate the sulphuric acid is precipitated with barium chloride, when the weight of the barium sulphate shows the total weight of combined sulphur in the ultramarine. Alumina is then precipitated by ammonia, and in its filtrate, after removing baryta by means of sulphuric acid, the soda is determined as sulphate. The properties required by consumers of ultramarine are a deep and brilliant color, fineness, tinctorial power and resistance to alum and to acids. All these points are determined by comparative trials with a standard specimen. Papers or textile materials tinted with aniline-blues on exposure to the sun are bleached often in a few hours. No

other blue employed for this purpose fades so rapidly. Papers, etc., tinted with ultramarine or with cobalt leave a blue ash on incineration. If ultramarine has been used the ash is decolorized by the application of dilute acids, while the shade of cobalt, on the contrary, is brightened by this treatment. Papers, etc., blued with Prussian blue, yield on ignition an ash which gives the reactions of iron.—*Chem. News.*

THE KANE GEYSER WELL.

By CHAS. A. ASHBURNER.

The Kane Geyser or Spouting Water Well, which during the past year has attracted such general attention from the "sight-seeing" public, is no novelty to the oil man. The cause of the action has been so erroneously represented that a correct explanation seems to be demanded.

This well is situated in the valley of Wilson's Run, near the line of the Philadelphia and Erie Railroad, four miles southeast from Kane. It was drilled by Messrs. Gruhout and Taylor, in the spring of 1878, to a total depth of 2000 feet. No petroleum was found in paying quantities and the casing was drawn and the hole abandoned, since which time it has been throwing periodically—10 to 15 minutes—a column of water and gas to heights varying from 100 to 150 feet.

During the operation of drilling, fresh "water veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2000 feet.

When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed into the well and the conflict between the water and the gas commenced, rendering the well an object of great interest. The water flows into the well on top of the gas, until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an explosion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of 13 minutes and the spouting continues for 1½ minutes. On July 31st Mr. Sheafer (aid McKean County) measured two columns, which went to heights respectively of 120 and 128 feet.

On the evening of August 2, I measured four columns in succession, and the water was thrown to the following heights: 108, 132, 120 and 138 feet.

The columns are composed of mingled water and gas, the latter being readily ignited. After nightfall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended, that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy.

During sunshine the sprays form an artificial rainbow, and in winter the columns become incased in huge transparent ice chimneys. A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have attracted such attention. As early as 1833 a salt well, drilled in the valley of the Ohio, threw columns of water and gas at intervals of ten to twelve hours to heights varying from 50 to 100 feet. This well is possibly the first of the "water and gas geyser wells."—*Stowell's Petroleum Reporter.*

DECOMPOSITION OF CHLORINE.

Mr. Fred'k Barkas, of the Zurich Polytechnikum, writes as follows: "A most important chemical discovery has just been made by Herren Victor and Carl Meyer, of the Polytechnikum, Zurich. Herr Victor Meyer had been making a number of experiments to determine the vapor densities of some organic compounds whose constituents were doubtful. Having invented a new and simple apparatus for the purpose, in order to determine its accuracy he made several experiments to test the vapor density of the commoner elements—oxygen, etc.—at temperatures from 100°C. (boiling water) to 1567°C. (heat given by a gas furnace). At length he tried chlorine, which gas was obtained by heating pure dry bichloride of platinum, but the results were not in accordance with theory. When the gas was heated at temperatures under and up to 620°C. it gave a vapor density of 2·46, while theory gives 2·45. This was very good; but at 808°C. the density was only 2·20. At 1028°C. it gave 1·87, while at from 1242°C. to 1567°C. the density remained nearly constant at 1·64 average. From this it was to be inferred that two molecules of chlorine at temperatures above 1200°C. break up into three molecules. Next came the question,

Does this arise from an alteration of the molecular constitution of chlorine, or from an actual decomposition into some new gases; in other words, is chlorine an element? Thereupon the expanded chlorine gas was slowly caused to stream into a fluid that absorbs chlorine. Potassa, iodide of potassium and mercury were all used for the purpose, and with the same result—a gas accumulated in the measuring tube that was not chlorine, but oxygen. Chlorine was thereby proved to be not an element but an oxide of some new element. A number of careful investigations were then made to be sure that the chlorine used was absolutely pure and dry, but with the same result. The new element, hypothetically called *Murium*, has not yet been isolated, but the learned professors are carrying out the important investigation with all diligence, so that doubtless within the course of a few weeks we shall hear more of the new element, *Murium*. That chlorine is an oxygen compound is not altogether a new idea. Sir Humphrey Davy, after his celebrated discoveries of the compound nature of soda and potassa, surmised that chlorine, iodine and brofnine were likewise oxygen compounds.

THE SUPPOSED COMPOUND NATURE OF THE ELEMENTS.

By J. Norman Lockyer, F. R. S.

Continuing my researches into the nature of the so-called elements, I have found that when carefully distilled metallic sodium was condensed in a capillary tube, placed in a retort and heated in a Sprengel vacuum, it gave off twenty times its volume of hydrogen. Phosphorus, carefully dried and submitted to the same treatment, gave off 70 volumes of a gas which appeared to consist chiefly of hydrogen. Although it gave some of the lines of phosphorus, it was not PH_3, as it had no action on solution of cupric sulphate. A specimen of magnesium, carefully purified by Messrs. Johnson and Matthey, gave me a magnificent series of colored phenomena. The hydrogen lines first appeared, then the D line—not the sodium line, be it understood, for the green line was absent—and, lastly, the green line of magnesium (*b*), and then, as the temperature was increased, mixtures of all these lines, with the blue line, the D line being always the most brilliant. In this experiment

only two volumes of hydrogen were collected. From gallium and arsenic no gas of any kind was obtained. From sulphur and some of its compounds sulphurous anhydride was always obtained. From indium hydrogen was given off in vacuo before heating, while from lithium no less than 100 volumes of hydrogen were given off. The conditions of the experiments were always the same, the only variable being the substance itself.—*Proceedings of British Association.*

PHOSPHORECENT PHOTOGRAPHS.

To Mr. Woodbury's inventive ingenuity we owe this plan, which has been tested, and is a practical success. The method he employs is known as the "dusting-on" process. It consists in coating a plate with a preparation of dextrine, honey and bichromate of ammonia, which, exposed under a negative, becomes hardened, where it is subjected to the action of light, through the transparent parts of the negative, remaining tacky where it is protected from the action of light by the denser parts of the negative. After exposure under a negative, the film, as it will be seen, is tacky in the lights of the picture, but hard and dry where light has acted on the shadows. The lights are therefore adhesive and tacky, retaining any fine powder which is dusted in or rubbed into the moist surface. At this point comes in the essential novelty. The powder to be used must be a phosphorescent substance. One of the best known and available is sulphide of calcium. A powder of this substance is applied to the image formed on the adhesive film, and sticks to it in due gradation of the tackiness, as regulated by the action of the light which passed through the negative. An image of sulphide of calcinm is thus formed, which, the powder being nearly white, is scarcely visible by daylight, but if the image be submitted for a time to sunlight, or bright daylight, or brilliant artificial light, and then taken into the dark, presents a luminous picture, somewhat startling, indeed, in the case of a portrait. A variety of substances possess this phosphorescent quality: sulphides of barium, calcium and strontium displaying it in the most marked degree; fluorspar, carbonate of lime, pearls, diamonds, phosphate of lime and arseniate of lime.—*Telegraphic Journal.*

Vibratory Forms of Circular Plates.—C. Decharme has extended the investigation of nodal systems, and drawn some interesting comparisons with the earlier researches of Chladni, who indicated three systems of nodal lines: the diametral, the concentric and the compound. He substitutes a thin layer of water or some similar liquid for the sand which Chladni employed, and finds many interesting relations among the peripheral and eccentric networks, the number of sonorous vibrations, the breadths of the striæ, the areas of the internodal sectors, and the numbers of nodal divisions. By means of these equations it becomes easy to estimate the wave lengths of different sounds.—*Ann. d. Phys. und Chem.* C.

Improvements in Calculating Machines.—Staffel has invented an arithmetical machine in which three cylinders are so arranged that they can work all the simpler rules of arithmetic, carrying multiplication up to millions by millions; if the machine is required to solve an impossible sum, such as subtracting a larger number from a smaller, or dividing a smaller sum by a greater, it refuses, and rings a bell as an admonition. Colmar invented an arithmometer in which the action is rather by plates sliding in grooves than by rotating cylinders; like Staffel's it can perform addition, subtraction, multiplication, division and evolution. Wertheimer, by means of a metal plate with indexes, notches, teeth and holes, has contrived an apparatus for adding and subtracting sums of money. Baranowski's invention is for calculating wages, prices, interest and other sums of money; it is known as the Ready Reckoner, and is worked by means of a handle which reveals figures or numerals in openings in a brass plate. Schott, Lalanne, Roget, Maurel, Roth, Slovinsks and Scheutz have in like manner invented machines for solving arithmetical problems. Of these, Scheutz's excites great admiration among scientific men; Mr. Babbage highly extolled it, and deplored that it had found a purchaser in America instead of in England. It can compute mathematical tables, calculate to sixteen places of figures, and stamp on a plate of lead the result up to eight places, producing a matrix or mould from which a cliche cast in type metal can be obtained, suitable for printing from; it does its work at the rate of twenty-five figures or numerals per minute, calculated, recorded and stamped in metal—an error either in the calculating or the printing being almost impossible.

Non-explosive Collodion.—Dissolve in alcohol and ether pure, well-washed gun-cotton; filter thoroughly and distil off the ether and alcohol until the thick residuum can be cast, while still warm, into moulds. After cooling, cut the gelatinous mass into bits, and dry them by evaporating the remaining alcohol. Dissolve again in alcohol and ether and the collodion will be neither explosive nor subject to spontaneous combustion.—*Chem. Ind.* C.

The Mineral Wealth of Great Britain.—The mineral wealth of Great Britain is shown by the fact, as officially stated, that the product of coal was, in 1877, 134,610,763 tons, as against 133,344,766 tons in 1876; of iron ore the product was 16,692,802 tons, against 16,841,583 the previous year; lead ore, 80,850 tons against 79,095 in 1876; tin ore, 14,142 tons, against 13,688 in the year before; copper ore 73,041 tons, against 79,252 in 1876, and salt, 2,735,000 tons. The total value of minerals and metals obtained from the mines, etc., of the United Kingdom in 1877 reached £68,281,405, viz.: £18,742,960, the value of the metals; £47,113,767, coal, and £2,424,679, minerals, earthy, not reduced, together with the value of salt, clays, etc. But the great item in these returns is the vast quantity—6,608,664 tons—of pig iron, of the value of more than $80,000,000, and it is estimated that in the manufacture of this metal between 15,000,000 and 16,000,000 tons of coal were used.

Molecular Constitution of Liquids.—R. Pictet has shown that in solid bodies there is a simple relation between their atomic weight, their length of calorific scintillation, and their temperature of fusion. This relation is a consequence of the universality of the laws of attraction, and of the most simple representation of the temperature, regarded as the *amplitude* of the calorific oscillations. On passing from the solid to the liquid state, each solid molecule should contain at least two liquid molecules. Since the molecular cohesion of all bodies is equal at the melting point, on departing from that point the lengths of calorific oscillation should be functions of molecular masses for equivalent aberrations of temperature. If we compare all liquids at their boiling points we should be able to deduce the same numerical formula as for solids. Pictet confirms these views by a comparison of theoretical and observed results in twenty-three solids and sixteen liquids.—*Comptes Rendus.* C.

Number of Oscillations in a Musical Note.—Pfaundler concluded, from observations with a siren, that two oscillations were sufficient to produce a note. Felix Auerbach, from a combination of physiological, psychological, physical and musical considerations, finds that probably about twenty oscillations are necessary. His views are confirmed by previous observations of Exner, Von Kries and Toepler.—*Ann. der Phys. und Chem.* C.

Large Map of the Solar Spectrum.—M. Thollon has exhibited to the French Academy a map of the visible portion of the solar spectrum, carefully executed in Italy, with the help of his large spectroscope. It is 10 metres (32·809 ft.) long, extending from A to H, and exhibiting about 4000 lines. Angström's map contained 1600 lines, and was 3 metres long. He calls special attention to the singular resemblance between the groups A and B, which never before have been so completely resolved, and proposes the following classification of lines: 1. Lines formed by a nebulosity without nucleus. 2. Lines consisting of a nucleus without apparent nebulosity. 3. Lines having both nucleus and nebulosity, the latter predominating. 4. Lines having nucleus and nebulosity, the former predominating. He gives a description of his apparatus, and states that the only precaution necessary in using it is to guard the prisms carefully from any variation of temperature.—*Comptes Rendus.* C.

Mechanical Operation of Sound-Waves.—K. H. Schellbach and E. E. Boehn have experimented with waves of sound, in illustration of the wave theory of light. Connecting two Leyden jars with the conductors of a Holtz electrical machine, so as to produce sparks of 1 centimetre (·39 in.) between the balls of the discharger, concentric rings were formed in coal-dust sprinkled on a glass plate 4 centimetres (1·57 in.) from the balls. The longer the spark the more strongly marked were the rings. By reflecting the reports of the discharges, by means of parallel walls and mirrors of various kinds, the dust-waves were made to assume such forms as are theoretically deducible from the reflection and refraction of light, thus visibly confirming the views of Huyghens and Young. That the results are not modified in any way by mere electrical action can be readily shown by substituting explosive gas or powder for the sparks. From ten to twenty sparks or explosions were generally sufficient to show the character of the waves and of their nodal intersections.—*Ann. d. Phys. und Chem.* C.

Proportion of Carbonic Acid in the Air.—The chemical text-books, almost without exception, hand down the classical and quasi-official assertion, that the atmospheric air contains a small quantity o carbonic acid, varying usually between 4 and 6 ten-thousandths in volume. On examining the reports of the most careful experimenter we find nothing to justify this narrow limitation; under the same meteorological conditions, at intervals of a few hours, the figures are often doubled. J. Reiset has experimented in open fields, far from any dwellings, with aspirators containing about 600 litres (158·51 gal.), and with ingenious precautions for securing the utmost possible accuracy of results. He never found so large a proportion of carbonic acid as 4 ten-thousandths. The range, in his summary, is between 2·829 and 3·178, and the mean 2·942 ten-thousandths. In the rue de Vigny, near the Parc Monceau, Paris, during the month of May, the mean of three years' observations was 3·027 ten-thousandths. The extreme variations did not exceed ·00003. In order to study the relations between these variations and the states of the atmosphere it would be necessary to use methods which would give results true to ten-millionths.—*Comptes Rendus.* C.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 15th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 125 members and 53 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that, at the last meeting, six persons were elected members of the Institute, and reported the following preamble and resolutions passed by the Board.

WHEREAS, We have learned with deep regret the death of our fellow member and Vice-President of the Franklin Institute, Mr. CHARLES S. CLOSE, therefore

Resolved, That by this event our Institute has lost an earnest and most efficient officer, and the community a most valuable citizen.

Resolved, That we offer our condolence to his bereaved family, and will attend his funeral at the appointed hour.

Resolved, That these proceedings be entered on our minutes and be published.

The Secretary reported the following donations to the Library:

Second, Fourth, Ninth to Sixteenth, Twentieth to Twenty-eighth Annual Reports of the Spring Garden Institute, Philada.
From the Institute.

Reports of the Principal and Professors of the Imperial College of Engineering. Tokei, Japan. From the Smithsonian Institution.

Reports upon the Survey of the Boundary between the territory of the United States and the possessions of Great Britain, with one Atlas.
From the Secretary of State, Washington.

Report upon the U. S. Geographical Surveys west of the 100th meridian. Vol. 5. Botany.
From the Chief of Engineers, Washington.

Transactions of the Institution of Civil Engineers of Ireland. Vols. 1—9 and Vol 11, in 13 parts. From the Institution.

First Biennial Report of the State Board of Agriculture for 1877–8.
From A. Gray, Secretary.

Annual Reports of the State Board of Health of the State of Michigan. For 1871—1878.

Lecture on Healthy Homes for Farmers. By K. C. Kedzie, M. D.
From the State Board of Health.

Report on Life-Saving Apparatus. From the Chief of Ordnance.

Annual Report of the Secretary of Internal Affairs of the Commonwealth of Pennsylvania. Part 4. From A. H. Dunkel, Secretary.

The Compendium of Architectural Sheet-Metal Work, Salem, Ohio, 1876. From Dr. W. H. Wahl.

Documents relating to the History of the Dutch and Swedish Settlements on the Delaware River. By B. Fernow. Vol 12. Albany.

Eighty-eighth Annual Report of the Regents of the University of New York.

Sixty-first Annual Report of the Trustees of the New York State Library.

Thirtieth Annual Report on the New York State Museum of Natural History. By the Regents of the University of New York.

Principle of Least Action in Nature. By Samuel Houghton.

Programm der Polytechnischen Schule zu Carlsruhe.

A Series of Familiar Lectures on the Elements of Scientific Knowledge most required in Daily Life. By Thos. Twining. Parts 5 and 6. London. From the Smithsonian Institution.

Proceedings of the Twenty-seventh Annual Meeting of the Board of Supervising Inspectors of Steam Vessels. From the Board.

Twenty-seventh Annual Report of the Trustees of the Public Library, Boston. From the Library.

Steam Engine. By W. Coute. Troy, New York. From the Author.

Examination of the North Carolina Uranium Minerals. By F. A. Genth. From the Author.

Fifty-eighth Annual Report of the Board of Direction of the Mercantile Library Association of New York. From the Association.

Obituary Notice of Isaac Hays, M. D. By S. D. Gross, M. D. Philadelphia.

Fourth Report of the Board of Trustees of Public Schools of the District of Columbia. From the Board.

Recent Accessions to, and Annual Report of, the Astor Library. From the Library.

Annual Report upon Explorations and Surveys in the Department of the Missouri. By E. H. Ruffner. From the Chief of Engineers, Washington.

Distribution of Heat in the Spectra of various sources of Radiation. By W. W. Jacques. From the Author.

Report of the Select Standing Committee on Immigration and Colonization. Ottawa, Canada.

Beiträge zur Beleuchtung der Allgemeinen Verhältnisse der Oesterreichischen Eisenbahnen. Wien. From M. Ritter von Pischof.

Eighth to Tenth Annual Reports of the Geological Survey of Indiana, made during 1876—1878. By E. T. Cox. From John Collett, Chief of Bureau of Statistics and Geology.

Lessons in Cookery. By E. A. Youmans. From M. L. Dods.

Reports upon the Specimens obtained from Borings made in 1874, between the Mississippi River and Lake Borgne.

On the Use of the Barometer on Surveys and Reconnoissances. From the Chief of Engineers.

State of Labor in Europe. Reports from the U. S. Consuls in the several Countries of Europe on Rates of Wages. From the Secretary of State, Washington.

Fifty-seventh and Fifty-ninth Annual Reports of the Managers of the Apprentices' Library Company of Philadelphia.
From the Company.

Historical Records of Port Phillip. By J. J. Shillinglaw.
From W. H. Odgers, Melbourne, Victoria.

Bulletin of United States Geological and Geographical Survey of the Territories. Vol. 5, No. 1.
From the Secretary of Department of the Interior.

Geological Survey of Canada. Mesozoic Fossils. Vol. 1. By J. F. Whiteaves. Montreal.
From the Geological Survey of Canada.

Meteoric Fireballs seen in the United States during the year ending March 31, 1879. By Prof. Daniel Kirkwood. From the Author.

Fifth Annual Catalogue of Central University, Richmond, Ky.
From Prof. T. W. Tobin.

Report to His Excellency the Governor, of the Thirty-seventh Missouri Catalogue. From the University.

Annals of the Astronomical Observatory of Harvard College. Vol. 11, Part 1. By E. C. Pickering. From the College.

Commissioners of Patents Journal. July, 1 and 4.

Abridgments relating to Lace-Making, Knitting, etc. London.
" " Cutting, Folding, etc., Paper. "
" " Agriculture. Division 2. "
" " Letterpress and similar Printing. "
" " Printing. "

Drawing, No. 2745 of 1878.

Specifications Nos. 3050, 3051, 3052 of 1807; No. 5633 of 1828; No. 12,430 of 1849; No. 2995 of 1860; No. 1082 and 2118 of 1864; No. 2620 of 1867; No. 2784 of 1876.

Disclaimers No. 385* of 1876; No. 3256 of 1877; and No. 995* of 1878.

Subject-Matter Index of Patents Applied for and Patents Granted. London.

Alphabetical Index of Patentees and Applicants for Patents of Invention. London.

Specifications and Drawings. Vols. 22, 25—38. London.
From the Commissioners of Patents, through Mr. Fred'k Ransome.

Mr. H. P. M. Birkinbine read a paper on the "Future Water Supply of Philadelphia," and some remarks were made on the subject by Mr. Thomas Shaw.

Mr. Jawood Lukens read a paper on an "Improved Puddling and Heating Furnace," of which he is the inventor, and diagrams of it were thrown upon the screen.

Mr. Bilgram explained the Improved Wire Sewing Machine for books, illuminated diagrams being used; and a machine in operation was also shown, Mr. Lever giving a number of practical details, and exhibiting samples of the work.

The Secretary's report included new forms of Meaker's automatic coin cashiers and money trays, rubber scrubbing brushes, and patent shawl straps. A number of beautiful photographs were exhibited, of Krupp's great establishment at Essen, and of the guns he has manufactured at different times, the gift of Mr. A. G. Buzby to the Institute.

Mr. Robert Briggs read the following memorial of our late Vice-President, Mr. CHARLES S. CLOSE, which, on motion of Mr. Weaver, was ordered to be printed in our minutes.

CHARLES S. CLOSE was born in the old city of Philadelphia, on the 20th of April, 1817. His father, a seafaring man, was mate of a vessel at the time of his death, in 1827, when the mother was left with little means of support for herself and family of four small children, of whom Charles, the subject of this memoir, was the eldest. A common school education of no high order at that time in the city of Philadelphia, which terminated at the age of ten years, when his father died, was all the education which the future master builder and member of the Board of City Surveys received for his commencement in life.

For three or more years he had employment in various ways, one of which was as an errand boy in a printing office, where he mastered the art of working the hand presses and became proficient as a ball boy. At the Exhibition of the Franklin Institute in 1874, as an indication of the progress of the art of printing, some presses of forty years before were shown. They were operated with much *eclat* by the venerable Mr. Hector Orr and Mr. CLOSE after the method of their time. Mr. Orr was foreman in the printing office of Charles Alexander, where the boy CLOSE was employed.

About 1834 he was apprenticed to learn the trade of a house carpenter to a Mr. John Countiss of the city of Philadelphia. At the end of three or more years the indentures were cancelled by agreement, for reasons entirely creditable to the young man. While under the pupilage of Mr. Countiss, however, young CLOSE became an excellent workman, so that before he was twenty years of age he received the highest wages paid journeymen.

He has been known to say that when he left school he could only do a sum in long division, but he had an early love for books and studious habits, and he bought all he could and studied to educate himself in the practical way as a builder and constructor. Some friend in the seafaring line interested him in nautical matters and gave him some instruction in elementary navigation. With an excellent constitution, perfectly abstemious habits, a quick wit which gave expression to a hearty enjoyment of every thing properly enjoyable, and with aspirations to learn and a will to perform, he was, in his young days, a companion for any around him, and a leader of men.

During his minority his small earnings and savings were absorbed by the wants of the family, so that his acquisition of knowledge, which formed the foundation of his future success, was made under many difficulties. To the end of her life he was an affectionate son and the chief reliance and support of his mother, whose efforts and sacrifices in his behalf in the time of his youth he often recalled.

About 1839 or 1840 Mr. CLOSE went to Mobile to find employment as a carpenter, but his stay was very brief. Fortunately or unfortunately he acceded to the request of a bright negro to show him the letters of the alphabet, which he did publicly, but yet with the then inevitable result, that it was desirable for the teacher to return to the North with some promptness. The return voyage to Boston brought out a curious instance of the advantage of general information.

The captain of the bark *Coosa* became insane on the passage; the mate proved utterly incompetent as a navigator, and the crew, with the two or three passengers, elected Mr. CLOSE captain, as the only one acquainted at all with navigation and knowing how to handle the vessel. Capt. CLOSE brought the vessel safely to Boston harbor [on a winter run]. Shortly after this time Mr. CLOSE went to Brazil with intention of settling, but although his prospects were very bright, continued illness induced him to return to Philadelphia.

About 1843 he became established as a carpenter and builder in the district of Southwark, and in that year he completed his first contract. Business grew rapidly upon him, and although he never took large contracts, he quickly had a remunerating business in its way.

In 1849, May 4th, he was elected Surveyor and Regulator for the district of Southwark. At this time he had never made a survey, nor is it probable he had ever used, much less owned, an instrument—level, surveyor's compass or transit. His fitness to accomplish anything he could be induced to undertake was thus generally admitted, and there were some special reasons why his fellow citizens thought it desirable he should take this unsought-for place. With one interval of five years, when some political causes effected a change, Mr. CLOSE has been elected and has held the office of Surveyor and Regulator of Southwark, or the corresponding district in the southern part of the city of

Philadelphia, for thirty years. The surveys and grades of the district when he commenced were in great confusion; under his direction and mostly by his own hand they have been completely revised and established. There is now no question possible as to the competency of Mr. CLOSE as a skilled surveyor. When Mr. CLOSE became Surveyor of the District he in great degree gave up his direct business as a contracting builder, and in course of a few years had a practice, more or less extended, as an engineer in construction of several kinds; in this way he was very successful in planning and directing work.

As a business man he has been eminently prosperous, and he became a considerable property holder in the southern part of the city. He has been President of the Seventh National Bank of this city the past four or five years.

Mr. CLOSE joined the Franklin Institute in 1855, was elected a member of the Board of Managers in 1864, and has been Vice-President of the Institute since 1875.

Mr. CLOSE frequently, of late years, attributed to the instruction imparted by the lectures and at the meetings of the Franklin Institute his acquisition of knowledge which so elevated him in his place as a working man, and often expressed his devotion to the interests of the Institute, saying that only in that way could he repay his indebtedness.

He was a man to whom life was thoroughly enjoyable, unruffled by petty annoyances, above any suspicion of meanness, intolerant only of any pretence, he enjoyed the respect and affection of all who knew him. Unassuming himself, he resented nothing but assumption by others, and his resentment evaporated in the words with which he would happily rebuke any impropriety. Integrity was associated with with every thing he did or allowed to be done, with every undertaking with which he was connected. Mr. CLOSE was a liberal man; no charity or beneficence failed to receive his sympathy and support with the largest liberality in money, and his time was always given freely for such purposes. He was associated with all the charities and public enterprises of his section of the city.

In his family he was very happy, and of those who knew him—an almost innumerable number—all were warm friends and associates, holding his company in high esteem.

He died on the 10th of October, 1879, at his residence on Reed Street, regretted by all, and especially by the members and officers of the Franklin Institute, with whom he had been so long connected.

Mr. Hector Orr offered resolutions of regret at the death of Mr. CHARLES S. CLOSE and Mr. HENRY C. CAREY.

On motion, the meeting adjourned.

ISAAC NORRIS, M. D., *Secretary pro tem.*

RECENTLY PUBLISHED.

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ERRATUM.—In Mr. Nystrom's article on Steam Boiler Explosions, in the last number of the Journal, page 256, line 21st, for "usual," read "regular."

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He was a man to whom life was thoroughly enjoyable, unruffled by petty annoyances, above any suspicion of meanness, intolerant only of any pretence, he enjoyed the respect and affection of all who knew him. Unassuming himself, he resented nothing but assumption by others, and his resentment evaporated in the words with which he would happily rebuke any impropriety. Integrity was associated with with every thing he did or allowed to be done, with every undertaking with which he was connected. Mr. CLOSE was a liberal man; no charity or beneficence failed to receive his sympathy and support with the largest liberality in money, and his time was always given freely for such purposes. He was associated with all the charities and public enterprises of his section of the city.

In his family he was very happy, and of those who knew him—an almost innumerable number—all were warm friends and associates, holding his company in high esteem.

He died on the 10th of October, 1879, at his residence on Reed Street, regretted by all, and especially by the members and officers of the Franklin Institute, with whom he had been so long connected.

Mr. Hector Orr offered resolutions of regret at the death of Mr. CHARLES S. CLOSE and Mr. HENRY C. CAREY.

On motion, the meeting adjourned.

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